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UNITED STATES CIVILIAN SPACE PROGRAMS: AN OVERVIEW

REPORT

PREPARED FOR THE

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

NINETY-FIFTH CONGRESS

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LETTER OF TRANSMITTAL

U.S. HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE AND APPLICATIONS,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, D.C.

Hon. OLIN E. TEAGUE,
Chairman, Committee on Science and Technology.

DEAR MR. CHAIRMAN: I am forwarding herewith the first volume study prepared by the Science Policy Research Division, Congressional Research Service of the Library of Congress entitled United States Civilian Space Programs. This first volume constitutes an overview and a second more detailed report will be completed at a later date.

This document provides a summary of many facets of the United States civilian space program and identifies issues for possible consideration by the Committee during the 96th Congress.

This study will have a continuing value to the Committee and to the government, university, and industrial community dealing with opportunities and issues of the space program.

Sincerely,

DON FUQUA, *Chairman,*
Subcommittee on Space Science, and Applications.

LETTER OF SUBMITTAL

THE LIBRARY OF CONGRESS,
CONGRESSIONAL RESEARCH SERVICE,
Washington, D.C., November 17, 1978.

Hon. DON FUQUA,
Chairman, Subcommittee on Space Science and Applications, Committee on Science and Technology, U.S. House of Representatives, Washington, D.C.

DEAR MR. FUQUA: Pursuant to your suggestion to the full committee, and the committee's subsequent letter of request, the Science Policy Research Division of the Congressional Research Service has undertaken a study of the United States civilian space program. The first volume of that study, which constitutes an overview of the progam, is submitted herewith. A second, more detailed report will be submitted at a later date.

The purpose of this first document is to provide a summary of the many facets of the U.S. civilian space program, and to identify issues which might become matters of congressional consideration during the 96th Congress.

Marcia S. Smith, Analyst in Aerospace and Energy Technology, coordinated the study, and was responsible for writing the introduction and summary, chapters 6, 9, 11, and 12, and portions of chapters 4, 15, and 16. George N. Chatham, Specialist in Aeronautics and Space, wrote chapter 3; Christopher H. Dodge, Specialist in Life Sciences, wrote chapter 8; Barbara A. Luxenberg, Analyst in Aerospace and Energy Technology, wrote chapters 7, 13, and 14, and portions of chapters 4, 15, and 16; Lani H. Raleigh, Analyst in Aerospace and Energy Technology, wrote chapter 10 and portions of chapters 15 and 16; and Charles S. Sheldon II, Chief, Science Policy Research Division and Senior Specialist in Space and Transportation Technology, wrote chapter 5. All authors contributed to chapter 2, Issues for Consideration.

In addition, the invaluable assistance of Brian Smith, currently of the Congressional Reference Division, Congressional Research Service, and Eleanor Burdette of NASA's Headquarters Library should be noted, for help in obtaining background research materials. Thanks are also extended to Dr. Sherman Vinograd of NASA for providing voluminous background information of a historical nature.

Sincerely,

GILBERT GUDE, *Director.*

UNITED STATES CIVILIAN SPACE PROGRAMS: AN OVERVIEW

By Marcia S. Smith, George N. Chatham, Christopher H. Dodge, Barbara A. Luxenberg, Lani H. Raleigh, Charles S. Sheldon II

Science Policy Research Division

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CHAPTER ONE

INTRODUCTION AND SUMMARY

By Marcia S. Smith
Analyst in Aerospace and Energy Technology

The United States space program is now 20 years old. The time is ripe to review what has been accomplished in space flight during this period and examine what may lie ahead. This report summarizes the era of space flight in the United States, but only civilian programs. Military space programs are not within the purview of this study.

There are many facets to the civilian space program, from the universities, and Government and industrial centers and facilities which support the space program, to the launch vehicles used for lifting spacecraft into orbit, to the spacecraft themselves, to the tracking systems used to follow spacecraft in their journeys, to the Government agencies responsible for conducting the space program or using the information derived therefrom, to the people who benefit from technological advances, such as rechargeable pacemakers, possible because of the space program.

The manned space program, which saw six two-man crews land on the surface of the Moon and return safely to Earth, has received the most media and public attention and is, therefore, the best known part of the space program. There have been a multitude of other space flights, however, involving a wide variety of investigations and uses of outer space. Applications satellities which are used for communications, meteorology and earth resources purposes have become essential to our daily activities. Space science missions provide information on the Sun, which affects our climate, weather and communications, and on other stars and planets.

From the early explorations of space, we are now learning how to utilize the space environment economically for the benefit of all. It may be possible, for example, to construct electric power stations in orbit, using energy from the Sun, to supplement or replace current imports of oil. Through NASA's Technology Utilization Program, space technology has already been used to help solve Earth-bound problems, such as advancing the state-of-the-art for medical devices, energy storage systems, and fire retardant materials.

Critics of the approximately $4 billion annual NASA budget, however, have maintained that the money spent on civilian space programs would better supplement the some $200 billion the Nation annually applies to programs in human welfare, social services, and housing and urban development.

Since the U.S. space program began with the launch of Explorer 1 on January 31, 1958, the policy of the United States towards spaceflight has fluctuated dramatically, ranging from President Kennedy's

1961 mandate to land men on the Moon by the end of the decade, to the current program of a relatively low, level space budget providing for few new projects. The reversal reflected, for the most part, changing priorities during years of increasing inflation and social unrest.

President Carter issued two directives in 1978 designed to establish a cohesive space policy for his administration. The first directive, in June 1978, established a Policy Review Committee (Space) within the National Security Council, headed by Presidential Science Adviser Frank Press, to coordinate the activities of the many Federal agencies involved in some aspect of the space program. One of committee's first tasks was to formulate recommendations for the President regarding a civilian space policy. The committee's recommendations forming the second directive, were released in October 1978. Discussion of specific elements of these policies are included as appropriate in the chapters and issues which follow in this report. The full texts of the two statements are reprinted as Appendixes A and B.

Reaction to the new policy statements has been mixed, primarily because the statements do not seem to clearly enunciate the President's position on space. For example, the October release states that "As the resources and manpower requirements for shuttle development phase down, we will have the flexibility to give greater attention to new space applications and exploration, continue programs at present levels or contract them." Rather than provide a definitive policy on what level of space activities the President prefers to pursue, the statement simply sets out the three possible options.

This report does not attempt to set goals for the space program either, but only provides a synopsis of past achievements and selected future programs to assist the House Science and Technology Committee in assessing the President's policy during the 96th Congress. Information in this report is current as of November 17, 1978.

CHAPTER TWO

ISSUES FOR CONSIDERATION

The purpose of a study such as this is to provide basic information about U.S. civilian space programs. Such a study would be incomplete without enumerating those issues which arose during conduct of research for the report, although it cannot hope to resolve those issues.

Following is a compendium of issues concerning these programs which may be considered in the 96th Congress. Each issue can be approached from various directions; for example, Congress could enact laws or otherwise direct the executive branch agencies in a manner to alleviate or resolve problem areas herein defined, whereas the executive branch could also act independently of Congress in resolving the issue. Therefore it seems inadvisable to separate these issues into those for resolution by Congress versus the Administration, since both branches could act on the issues either independently or in tandem.

Chapters three through sixteen, which follow, provide background information on the origin of the issue, although it should be noted that there may not be a precise correlation between the subject heading for the issue here and a subsequent chapter. For example, the possibility of a next generation space shuttle is listed under space shuttle issues here, while the background discussion can be found in Chapter Five, Launch Vehicles and Propulsion, not in Chapter Seven, Space Shuttle. For convenience, chapter numbers are provided in parentheses to direct the reader to that portion of the study containing further information.

A. ISSUES CONCERNING NASA AS AN ORGANIZATION

It may seem that after twenty years, the National Aeronautics and Space Administration (NASA) is a permanent fixture. But this is an age of sunset laws, and conditions change so that what may have been valid in 1958 is fair game for reexamination now.

Just as Congress and the executive branch have been rent in the past over issues of U.S. military power—as to whether we need to be more powerful than any potential enemy, or equally powerful, or merely able to deter hostilities—similar issues have surrounded the national posture in space.

1. Scale of NASA's operations (Chapter 3)

The enabling legislation which created NASA set forth general objectives for the agency both as to direction and the standards to be met ("preservation of the United States as a leader in aeronautical and space science and technology . . ."). Officials have debated whether the controlling article is "a" leader as opposed to failure of the Act to say "the" leader. Actual response to this goal depends upon

the behavior of foreign rival programs, and the capabilities and funding support made available in the United States. The degree to which leadership is sought and the speed with which it is approached in this country depends upon myriad decisions in the Federal budget proposed by the President and modified by the Congress. This support has not been consistent over the years.

The issue is, what necessity is there, or what national desire is significant, to support the space effort at prevailing levels, or at higher levels, or at lower levels? What are the tradeoffs of relative budget priorities, fiscal pressures, economic growth, economic well being, technology development, world bargaining position, and intangible values to help us find an appropriate level of space funding?

2. NASA limited to research or allowed operating authority? (Chapter 3)

Section 102(c)(3) of the National Aeronautics and Space Act of 1958 states that the aeronautical and space activities of the United States shall be conducted so as to contribute materially to the objective of "development and operation of vehicles capable of carrying instruments, equipment, supplies and living organisms through space." Section 103 defines "aeronautical and space activities" as "the development construction, testing and *operation for research purposes* of aeronautical and space vehicles" (emphasis added). Those who drafted the Act in 1958 were not of one mind at that time as to what limits should be imposed on NASA's authority, and various interpretations of the language in the Act have been made since.

Can government user agencies or private industry conduct operational programs with greater efficiency than NASA? Would operational programs under NASA divert money and attention from needed research and development activities? What kinds of increases in staff and funding would be required if NASA were to be responsible for operational programs, and would these increases be feasible politically? Would specialized user interests be adequately considered if NASA managed operational programs?

Aviation. Does the long history of the National Advisory Committee on Aeronautics (NACA, NASA's predecessor), which was narrowly confined to supporting aeronautical research, carry over more limits on NASA in aviation activities than it does in space?

Space Applications. Meteorological and communications satellite programs, upon reaching an operational capability, have been transferred to the National Oceanic and Atmospheric Administration (NOAA) and the Communications Satellite Corporation (Comsat) respectively. Supporting and developmental research in these applications areas has continued at a modest level in NASA and launch services have been provided by NASA, but the main operational responsibility for the satellites themselves has been left to the other organizations. Are the past reasons for such transfers still valid now? Will sufficient development of advanced applications in these fields come from NOAA and Comsat?

A new situation is presented by the Landsat experience. Is Landsat sufficiently developed that it is ready for operational use? Are there legal reasons Landsat should not be termed operational? Because Landsat will have many different uses, is there any single existing agency which has a sufficiently broad perspective that it could meet

the needs of multiple users? Should there be international controls on operations in the Landsat type of activity? Are there military reasons why Landsat should be operated by the Department of Defense? Could a private or quasi-public corporation function in the Landsat area as is the case in communications? What responsibilities for development and operation should or should not be urged on NASA in future space applications systems?

Space Transportation. NASA's charter seems clear with respect to launching and operating research payloads, and developing the means to conduct space flight. Once the space shuttle becomes operational, and it is used for both scientific and applications purposes, what restrictions, if any, should apply to NASA authority to operate this system? Would the Act have to be revised to make explicit the NASA authority to operate the shuttle for all users, as well as carry on other operations in the applications area? Were the reasons for transferring operational applications programs to other agencies in the past valid now for the shuttle?

3. Military versus civilian control of space technology and operations (Chapter 3)

During the 1950's, President Eisenhower selected the Naval Research Laboratory (NRL), with a largely civilian team, to construct the civilian launch vehicle and satellite (both called Vanguard) in preference to using the Army Ballistic Missile Agency's Redstone Arsenal Team because the President wanted to emphasize his position that space be used for peaceful purposes. The latter group was brought into the satellite business only after the first Vanguard launch failed in December 1957, and an existing Army hardware system was used to launch the first U.S. satellite, Explorer I, on January 31, 1958.

There were many contending agencies which wanted the prime role in space as the National Aeronautics and Space Act was being written. The President selected the civilian National Advisory Committee on Aeronautics (NACA) which had worked for many years, primarily for the military services, as an agency for conducting aeronautical research. The new National Aeronautics and Space Administartion (NASA) not only expanded NACA's mission into space, but had broad authority to contract with industry and even with the military departments, as well as bulding its own research and development centers. The Army's Redstone team, the Army's Jet Propulsion Laboratory at the California Institute of Technology, and the NRL's Vanguard team were all transferred to NASA once the agency was established. While the Act, as proposed by the President and as rewritten by Congress, gave NASA a key role in leading the national space program, the right of the Department of Defense to conduct military operations in space and the research necessary to such operations was protected, and the Air Force was given responsibility for military space programs. Mechanisms were created to coordinate the NASA and DOD space efforts. For some years the National Aeronautics and Space Council in the Executive Office of the President was one means for coordinating all U.S. space activities until it was disestablished by President Nixon in 1973. The Space Act had established a Civilian-Military Liaison Committee to coordinate the activities of NASA, Army, Air Force, Navy and DOD, but this committee was abolished in 1965. The Aeronautics and Astronautics Co-

ordinating Board was a bilateral body set up for improving technical level cooperation between NASA and DOD.

Do the two surviving major space research and development agencies (NASA and DOD) represent costly duplication, or can they coordinate programs and share technological developments sufficiently to work efficiently? One example cited as indicative of the level of NASA/DOD communication is the tracking and data relay satellite system (TDRSS) problem. Briefly, in the 1980's NASA is planning to rely on several satellites leased from Western Union for tracking, rather than its current world-wide tracking network. After NASA had developed the specifications for these satellites, and signed contracts with Western Union for them, it was found that routine radio frequency interference from Eastern Europe almost completely inhibited the functioning of the TDRSS. It appears that the Defense Department may have been aware of this problem but failed to communicate to NASA the necessity for TDRSS design modifications to avoid the interference problem. What can be done to smooth channels of communication between DOD and NASA to eliminate the possibility of situations such as this developing in the future?

Do the efforts of NASA and DOD complement each other? Does the area of potential overlap provide a stimulus to progress through competition?

What would be the consequences of a merger of the NASA and DOD efforts in space? Would the surviving agency necessarily be subordinate to DOD? Would military control of the entire space program set lower priority on scientific and civil applications that border on military interest such as increasing sensor resolution for earth resources satellites? Is there sufficient technology transfer and sharing of facilities and equipment under the present coordinating patterns, and would these be improved if there were but a single agency conducting space work?

What would be the effects on international cooperation if the U.S. agency were DOD instead of NASA? Would the willingness of universities and individual scientists be influenced differently if they were working with DOD instead of NASA? Would there be a greater tendency to classify space information which now, on the NASA side, is relatively open?

If NASA and DOD keep their separate activities and capabilities in space, are there special problems that need to be resolved in relation to management of the space shuttle? The DOD may be the principal user of the shuttle. Should it have complete operational control of its own shuttles, or should it manage all the shuttle craft and facilities? How would military management of the shuttle affect NASA programs, civilian applications, and foreign customers for launch services? How would NASA be changed if it were restricted to research, development, and conducting science experiments, losing its launch capabilities to DOD? Would DOD necessarily set its priorities first, and care for NASA and other clients only with its excess capacity when available? Could NASA conduct its missions without its present level of control over launch scheduling and operations?

4. NASA cooperation with other government agencies (Chapter 13)

Data returned from satellites (such as meteorological and earth resources) can be of great value to many agencies of the government.

Is communication adequate between NASA and the potential user agencies for the best utilization of data from satellites? Does NASA's charter need to be revised to cut across interagency boundaries to fully utilize data returned from NASA satellites?

Would there be value in establishing a global information system supported by all civilian sensing spacecraft? If so, how would the necessary interaction and cooperation be achieved between NASA, the Environmental Protection Agency, the Agency for International Development, and the Departments of Agriculture and Interior, to achieve a workable system? Is the Earth Resources Observation System Data Center in the Department of Interior able to be responsible to U.S. needs for space-derived data? How might its responsiveness be expanded?

5. Communication Satellite R. & D. (Chapter 10)

From 1960 to 1973, the Federal Government (primarily NASA) assumed the dominant role in communications satellite research and development (R. & D.). This research provided the basis for low-risk operational system development by private enterprise in the 1960's and 1970's. Since NASA's disengagement from an active R. & D. role in 1973, private industry has not assumed a broad-scale R. & D. activity. Some argue that industry has introduced improvements rather than innovations. Principal reasons cited include the large required financial outlays and the risks involved. A typical flight R. & D. program may cost in excess of $50 million per year over a three-year period, whereas the largest commercial communications satellite organizations have been able to set aside an average of $5 million per year for R. & D. activity. In addition, antitrust laws prevent pooling of private industry resources for collective research efforts.

While it is true that in the past the military communications satellite program has developed significant applicable technology, its contribution to commercial missions is hampered by an increasing divergence in military and civilian applications. For example, most of the military work is done at non-commercial frequencies and is thus of limited utility to commercial companies.

Whereas the U.S. Federal communication satellite R&D budget has been drastically reduced, other nations are sponsoring ambitious programs. Japan, Canada, and the nations of the European Space Agency have government-sponsored communications satellite R&D budgets several times greater than that of the United States. Without a strong R&D program, dominance by foreign countries of the strategic multi-billion dollar international communication satellite markets of the 1980's may be possible.

Should there be a revived strong federally sponsored communications satellite R&D program? What is the best way to encourage advanced communications satellite R&D? Are there regulatory mechanisms, such as revised antitrust laws and tax incentives, etc., which would encourage private sector R&D sufficient to enable the United States to maintain its international dominance in this field or is the risk in this area so high that the Federal Government should maintain its own program?

B. ISSUES CONCERNING NASA CENTERS AND FACILITIES

1. Number and role of NASA centers (Chapter 4)

To facilitate its transition from the Apollo era to the shuttle era, NASA conducted an institutional assessment study of its nine centers and the Jet Propulsion Laboratory (JPL). This study, completed in 1976, was aimed at assessing the roles and missions of each center and JPL to determine whether all were essential to the current space program. The result of the study was a significant realignment of roles and missions of eight of the ten installations. How has this realignment served NASA? Have savings accrued to NASA from this realignment on the order of the $20 to $25 million annually expected by NASA? Is NASA now organized properly for a logical transition from the Apollo era to the shuttle era? Does each center and JPL now have appropriate roles and missions assigned to it?

2. Performance of non-space work (Chapter 4)

Another issue relating to NASA centers is the question of whether they should engage in non-space work for other Federal agencies. NASA's Lewis Research Center, Dryden Flight Research Center, and the Jet Propulsion Laboratory, for example, all perform significant energy research. Should this research be more properly conducted by the Department of Energy (DOE), or is this research enabling more complete utilization of NASA facilities which otherwise might be underutilized? Would it make sense to transfer the Lewis Research Center, which does a large proportion of energy work (just under 30 percent), to DOE and transfer its space functions to another NASA center?

3. Effect of manpower cuts on NASA centers (Chapter 4)

Pursuant to the findings of its 1976 institutional assessment study and the Office of Management and Budget directives, NASA had planned to reduce agency employees by 583 positions (out of approximately 23,000) at its installations by the end of fiscal year 1978. Should an assessment be made to determine the results of this reduction on the functioning of NASA centers in performing their missions? If the reductions are not made from operating programs but rather from basic research and development (R. & D.), might basic R. & D. suffer from these manpower cuts? If reductions in personnel are continued beyond fiscal year 1978 levels, will NASA be able to retain all its centers or will a consolidation be necessary? Has the job cut adversely affected NASA's ability to perform its missions?

4. Contracted versus in-house R. & D. (Chapter 4)

Since its inception, NASA has developed both extensive in-house capabilities to do in-house research and development and extensive contractual relationships with industry for conduct of space R. & D. In a time of shrinking budgets and inflation, would it be less expensive for NASA to conduct its research in-house or by contracts? With reductions in personnel at NASA centers, does NASA have a diminished capability to conduct in-house R. & D.? What would be the cost/benefit of diminishing NASA's in-house capability for R. & D. (through personnel and funding reductions at NASA centers) and increasing its contracted R. & D.?

Another aspect of contracted vs. in-house R. & D. is the efficiency with which technology developed through government R. & D. can be transferred to the private sector. Studies have suggested that some technologies developed under contract to industry may be assimilated into the economy more quickly than technologies developed in-house. Would the benefits of space technology thus be transferred more quickly to the economy through contracted research? What parameters define the efficiency of transfer?

5. Effect of the shuttle on NASA centers (Chapter 4)

Because of the anticipated high launch rate of the shuttle once it becomes operational (approximately every week) and the requisite ground support for these missions, shuttle operations will significantly impact on two NASA centers: Johnson Space Center and the Kennedy Space Center. The shuttle utilization program will have a much broader effect and may impact on the size and direction of all NASA field centers. How is NASA planning for possible changes in the scope and direction of its field centers once the shuttle becomes operational? What impact might shuttle utilization activities and planning have on NASA center management?

6. Effect of Inflation on NASA centers (Chapter 4)

Despite intensive efforts to cut costs at NASA centers, the effects of inflation have begun to cut into the money for mission-oriented research activities and for services. What effect will this have on the ultimate missions and performance of each center? If maintenance of facilities is allowed to slide, will this adversely affect operational activities of the centers or cause more expensive overhauls in equipment in the future?

7. Facilities utilization program (Chapter 4)

On January 28, 1977, NASA issued a new management instruction on its Facilities Utilization Program. The prime focus of this instruction was to seek improved utilization and identification of under-utilized or excess technical facilities and buildings at NASA centers. Pursuant to this instruction, NASA issued a Major Facilities report which tabulated data on the extent of utilization of the technical facilities at each center. What impact, if any, has this study had on NASA FY80 planning for facilities utilization? What under-utilized or excess technical facilities were identified by this report and what plans have been developed for their increased utilization or disposal?

One possible way to increase utilization of NASA technical facilities would be to share them with researchers in industry, universities, and government. This would depend, of course, on awareness by the research community of the availability of such technical facilities. What would be an effective mechanism to disseminate information regarding such equipment? How might sharing of such technical equipment be facilitated by NASA?

C. ISSUES CONCERNING LAUNCH VEHICLES AND PROPULSION

The physical limits of rocket performance are well understood, and after exploratory engineering in various chemical, nuclear, and electric rocket systems, the main United States commitment of resources has

gone in recent years largely into the reusable space shuttle of the Enterprise class, which is still in final development before orbital flight begins in 1979 or 1980.

1. Heavy lift vehicle requirements (Chapter 5)

It is possible that there will be future needs to operate in orbit devices heavier than can be lifted by the presently developing space shuttle. These might include major communications relays, solar power stations, deep space expeditions, lunar stations, even future manned "colonies."

What are the tradeoffs in cost and reliability of assembling multiple payloads in orbit after carrying them up from Earth in the shuttle, versus supplementing the shuttle with heavy lift launch vehicles of larger capacity (which still would require assembly of some devices in orbit, but fewer units)? Some Saturn V launch vehicles remain in mothballs, but these are so few that at best they are only a temporary and limited solution to possible needs.

Are there some payloads in excess of the shuttle's capacity, such as larger nuclear reactors, or some advanced scientific and applications payloads, which will be important to lift, but which defy reasonable hope of assembling and checking out in orbit?

If a new heavy lift capability is needed, should it be developed from components of the current shuttle, or should a return be made to an expendable system? Would the high performance shuttle components be too expensive to use in an expendable system, or too difficult to use in an automated recoverable system? What would be the cost and performance tradeoffs of various types of heavy lift expendable systems, whether solid fueled or liquid fueled, and whether complex or simple?

2. Propulsion requirements to augment the shuttle (Chapter 5)

Regardless of how well the shuttle performs, it is designed to fly only a few hundred kilometers above the surface of the Earth, while many applications and science missions require an ability to reach geosynchronous orbit 35,800 kilometers above the Earth or to reach deep space, and also many orbital locations close to the Earth where it would not be economical to move an entire shuttle. Hence the need for upper stages and space tugs is already recognized. The degree of response to these needs has been limited more by budgetary problems than by questions of mission. How fast now should we move from interim and makeshift upper stages to more powerful and more versatile space tugs?

3. Environmental impacts from space launch systems (Chapter 5)

Heightened awareness about the importance of the environment has not escaped the space program, and possible risks include noise, atmospheric pollution, and ionospheric changes.

What can be done to minimize noise pollution from launch or reentry of space shuttles? Can the complex chemical products from the solid rocket boosters which lift the space shuttle lower atmospheric quality appreciably as the number of shuttle launches increases? Can water vapor from the main propulsion system of the shuttle affect the ozone layer of the ionosphere in any significant manner?

D. ISSUES CONCERNING APPLICATION SATELLITES

1. Operational Landsat (Chapter 10)

One of the major goals of the experimental Landsat program was to gain sufficient knowledge and experience to determine the advisability of establishing an operational Earth resources satellite system. After five years of experimentation and three Landsat spacecrafts, there is no comprehensive, long-range plan which will lead to a decision on whether or not to establish an operational system.

Congressional efforts to establish an operational system have reflected a concern that the uncertainty of continuous data availability restricts more extensive use of Landsat by many current and potential users. To realize maximum benefits from Landsat data, many experiments would require continuous data for extended periods of time. In order to justify such investments and before long-term experiments can be initiated, it is necessary to have some assurance of program continuance. A national commitment to go operational would, according to its proponents, provide the user community with the assurance it needs. Without such a commitment or a definite point of program termination, the experimental phase of the program will continue indefinitely, thereby leaving the users in a continuous state of uncertainty regarding the future. These congressional initiatives to establish an operational Landsat have encountered differences in philosophy regarding the appropriate institutional arrangement for the Landsat system and the best means of encouraging the participation of the private sector, but not in the need for an operational system.

Given the magnitude of the investment in data interpretation equipment and personnel training, the uncertainty of the commercial market, the non-aggregate status of the user community, and the fear of lack of support from the Federal Government, the private sector has been reluctant to establish its own operational system.

The current administration's position is that its funding of the fourth satellite, Landsat D, and its backup satellite demonstrate a commitment to a continuing Earth resources satellite program of sufficient duration and certainty to satisfy the user community. It is the administration's intention to establish an interagency task force to study expected technical, programmatic, private sector, and institutional arrangements for remote sensing, and to examine options for integrating current and future systems into a national system. The task force is expected to complete its review prior to the FY 81 budget cycle.

Given this postponement of establishment of an operational system by the administration, should Congress revive its efforts to establish an operational system? What are the consequences of waiting an additional three or four years to establish a system? With the progress of the French and Japanese remote sensing programs, are we risking losing our leadership in this area by not establishing an operational system now?

Opting for an operational system will require further decisions concerning what types of institutional arrangements are appropriate. Concurrent with this consideration is the issue of an appropriate role for the Federal Government in support of the development of the technology.

2. Aerosat (Chapter 10)

The Aerosat program was originally designed to be a cooperative program under which the United States, Canada, and the member nations of the European Space Agency (ESA) were to jointly develop an aeronautical communications satellite. Negotiations concerning this program have been on-going since the early 1970s, At several points during the conduct of these negotiations, the Europeans made agreements concerning Aerosat with U.S. Government agencies only to find those agreements negated by other branches of the Government. Continuity of U.S. funding for the program has never been assured by the United States, though the Europeans did make such commitments.

At the present time, it appears as though the Aerosat program may not be funded by the United States, despite previous agreements. Has this situation impacted adversely on our relationship with the Europeans and Canada? How might it affect U.S. credibility world-wide? Does the United States need to establish firmer guidelines on what branch of the Government or which organization may make commitments for the United States? Why were the conflicting interests of the United States not handled in a more orderly fashion? Did competing interests in both the U.S. Government and the private sector prevent a united U.S. position from developing in the negotiations?

What mechanism can be used to ensure that user interests are considered in the development of space technologies?

If a decision should be made now by the United States to proceed with the program, the program could not be implemented until the early 1990s. Would this mean that the system would be technically outmoded by the time it was implemented? If so, what problems might this create for the United States, Europe, and Canada?

More generally, given the long period between conception of a space program and its funding and implementation, coupled with possible additional time lags due to coordination of cooperative programs, is the problem of possible out-dated technology one which might face other cooperative space technology programs? Using Aerosat as an example, are there ways in which the decisionmaking process could be streamlined or hastened to help eliminate the possibility of space technology becoming outmoded prior to its implementation?

Does the Aerosat experience suggest that the United States should have proceeded on its own with a national aeronautical satellite if it needed one, and then have invited other nations to participate after the program had become a reality? What program will replace Aerosat? What technologies are under consideration to meet the aeronautical communications needs of the 1990's?

3. Navstar (Chapter 10)

The Navstar Global Positioning System (GPS) is a space-based radio navigation system designed to provide users with worldwide three-dimensional position and velocity information. It is currently a multiservice Department of Defense program designed to meet the future navigational requirements of the armed forces. The potential application of the system for civilian uses has prompted the proposal of a joint military/civilian Navstar program. If civilians will have access to the system, certain technical specifications will have to be incorporated into the technical design at an early date. At present it remains unclear, however, who would make the decision to initiate a

joint military/civilian Navstar. Is sufficient and timely consideration being given to the civilian use of the Navstar system? A fatal flaw of the Aerosat program was lack of user support. Is a formal executive branch policy decision concerning civil use of the global positioning system and establishing those forms of administrative mechanisms required to insure that the development of the system takes into consideration the needs of the civil users necessary? If the decision is made to authorize a joint program, who should manage the system?

4. Public service communications satellites (Chapter 10)

There are many potential satellite communications services, such as health care delivery, educational services, search and rescue, and teleconferencing, which cannot be economically provided by commercial communications companies. Should the Federal Government supply these services? To what extent? Until the public service user community is identified and aggregated?

Much of the research needed to lower the costs associated with public service communications satellites involve high risk investment which cannot be economically justified by commercial companies. Should the Federal Government support research and development to advance the technology so that at some point the services could be commercially supplied?

5. User needs (Chapter 10)

As more space applications programs pass the initial testing and demonstration stages, increasing concern is focused on user requirements. Consideration of user needs may impact on development of any space applications technology in terms of cost, hardware development, and operation of an applications system. Should user needs be considered to insure maximum effectiveness and use of experimental space technologies as they make the transition to operational status? If so, are new institutional arrangements, pricing policies, and management techniques necessary to best consider user needs? Domestic user needs may at some point conflict with international user needs; which shall prevail and under what guidelines?

The introduction of more advanced technologies into space applications programs may lessen those programs' utility to international users if the users are not equipped to handle the more sophisticated technologies (for example, the introduction of the thematic mapper to the Landsat system to the exclusion of the multispectral scanner). Does the United States have an obligation to provide a technology compatible with world capabilities and needs?

All indicators suggest that the developing nations perceive great value in applying space technology and data to their national needs and that they want to increase their access to, and use of, such technology and data. What could, and should, the United States do to increase the availability of space applications technology and data to the developing nations? Should special consideration be given to their needs, such as preferential pricing status?

In general, how should rates for space applications data be determined? Should the United States coordinate scientific experimentation with international user needs regardless of user ability to pay? Specifically, should a pricing structure be developed which will establish a sliding scale based on user needs and ability to pay? Should a

pricing policy be established to recover only developmental and operating costs rather than profit? What effect might this have on industrial participation in space applications?

How effective is NASA's technology transfer program in remote sensing? What are the major inhibitors preventing the States from using space-derived remote sensing data? Is the NASA program adequately funded?

6. Direct broadcast technology (Chapter 16)

The ability to broadcast directly into individual home receivers may be available in the near future. This technology has many potentially beneficial uses, but it is controversial in that many nations believe they may not have the desired control over the content of what is broadcast into the individual home receivers. The United States, along with other nations, has adopted a stance against prior consent because of its policy that the flow of data and information should be unimpeded and therefore should be subject to minimal regulation. In the interests of international promulgation of the beneficial uses of direct broadcast technology, might the United States and the nations sharing similar views modify their positions without compromising their basic policies in order to achieve a consensus in the United Nations on use of this technology? If so, what modifications would be acceptable? What role might the Congress have in assessing the U.S. position on this international issue?

7. Limitation to image resolution (Chapter 10)

Although very useful results have been achieved with Landsat data, many users require data with better image resolution (ability to distinguish individual objects). Landsats 1 and 2 have resolution limits of 80 meters, Landsat 3 has 40-meter resolution, and Landsat D will have a 30-meter capability. In planning future Earth resources satellite missions, the question of limitation of image resolution arises. Various reasons have been given for the fact that the technology for improved image resolution has not yet been implemented on civilian spacecraft. Some argue that the Department of Defense has imposed limitations to image resolution to prevent civilian spacecraft from providing highly detailed imagery to the public on the grounds that it could have military uses. Others claim that the higher resolution systems are very expensive and for reasons of economy, the Landsat spacecraft series has not been so equipped. Given the potential utility of the higher resolution systems to the user community, the necessity of image resolution limitations for national security and the desirability of funding the more advanced resolution systems for future spacecraft may be issues of congressional concern.

8. Is space policy keeping pace with technology? (Chapter 10)

Domestic communications satellite systems were proposed in the early 1960s. However, it was not until 1970 that the Federal Communications Commission (FCC) settled a long policy debate and issued its regulation permitting the implementation of domestic communications satellite systems for the United States.

Discussions of a potential business satellite system began as early as 1967. In 1977 the FCC issued a ruling which enabled the establishment of Satellite Business Systems (SBS), Inc. In August 1978 the

U.S. District Court of Appeals for the District of Columbia ruled that the initial FCC consideration was inadequate and a rehearing on the legality of SBS is necessary.

Landsat 1 was launched on July 23, 1972. Formal discussions of an operational system were initiated in 1974. In 1978 there is still no decision on an operational system.

The possibilities of civilian uses of the Navstar system first gained recognition in the early 1970s. As of late 1978, however, there is still no mechanism which will ensure that civilians will have access to the system or that the system will be designed to benefit the civilian sector to the maximum extent compatible with military goals.

Thus, a pattern emerges. There is often a significant time lag between technical development and policy decisions which often has serious consequences for space technology implementation. Policy problems typically involve issues concerning the transition from experimental to operational systems, the adequate consideration of user interests, and the reconciliation of regulatory and legal interests with technical developments. Are the present mechanisms and institutions adequate to ensure the early identification of policy problems in the implementation of new space technologies and the promotion of their use? Should new institutions be created for this purpose?

E. ISSUES CONCERNING NASA TRACKING SYSTEMS AND THE TDRSS

NASA's Tracking and Data Relay Satellite System (TDRSS) will consist of two specialized communications relay satellites in geosynchronous orbit and a ground terminal located at White Sands, New Mexico. With the existing network of ground stations, most low-orbit satellites are usually out of the sight of any station. The TDRSS system will increase the present 15 percent coverage provided by ground stations to 85 percent. Data will be relayed directly to and from the spacecraft and mission control centers, eliminating the need for costly and often unreliable recorders which currently store data on orbiting satellites, until they are in view of a ground station.

Each TDRSS satellite will be capable of simultaneous tracking and two-way communications with 20 or more scientific, applications, and manned spacecraft in Earth orbit at altitudes up to 5,000 kilometers. The system will offer an increase in wideband facilities to handle the high data rates needed for Landsat–D, Spacelab, and the space shuttle. Thus, TDRSS will enable NASA to phase out nine of its thirteen tracking stations, and to avoid the massive network update which would have been required to handle the wideband communications of future space missions.

1. Lease versus buy considerations (Chapter 10)

NASA chose to lease TDRSS system services from Western Union rather than purchase its own system. A major factor in this decision was an estimated cost savings with the lease option resulting from deferred expenditures. Have there been unforeseen costs associated with the lease arrangement which may have made the purchase option the less costly choice?

What are the intangible benefits of a leased system? Are there any special problems peculiar to a lease arrangement? With the political uncertainties of obtaining congressional approval for a large, expen-

sive project, does a lease arrangement, which enables NASA to exchange large initial financial outlays for smaller monthly lease payments, offer a more politically acceptable model for future space missions?

There will be a total of four operational TDRSS spacecraft in geosynchronous orbit. Two will be assigned to the NASA mission, the other two will be stationed so they can serve Western Union's domestic users. One of these will usually be operated in a shared mode, serving both. This shared spacecraft concept was a major factor in providing for a lower-cost system. Could this model of government/private industry cooperation be applied to other types of space applications programs?

2. Timing of TDRSS (Chapter 4)

The launch of the first TDRSS was originally scheduled for July 1980 with three satellites to be in orbit by mid-1981. Now it appears that there will be minimum of three months' delay for the launch of the first TDRSS due to delays in the shuttle launch schedule. What effect might this have on the tracking station contracts in other countries? With existing uncertainty in shuttle launch schedules, can the existing tracking network agreements be allowed to lapse? What would be the effect on the TDRSS of a slip in the shuttle time schedule of longer than three months, for example, from late 1979 to early 1980 (as there is some indication that there might be)?

3. Global tracking network (Chapter 4)

NASA's tracking network will become less important as the tracking and data relay satellite system (TDRSS) takes over most of the workload previously assigned to the tracking network. What costs will be saved by NASA due to the decrease in the global tracking network through using TDRSS? What technical risks might the Government be taking by primary dependence on the TDRSS for Earth orbital missions?

4. Radar interference problem (Chapter 10)

The vulnerability of TDRSS to interference from Eastern European radar signals is the subject of a contract dispute between NASA and Western Union Space Communications, Inc. The satellites must now be equipped with electronic circuitry which will prevent them from becoming overloaded with random "noise" produced by the radar as it beams out into space. Recognition of the interference problem became evident when NASA and the TDRSS contractors held a preliminary design review in the spring of 1978. Since the satellites were already in an advanced stage of design and construction, adding the necessary hardware will increase the cost of the $796 million project considerably. The question of who will be liable for the extra expense is the subject of current negotiations between NASA and Western Union. Liability will depend on the determination of who was responsible for the error, based on whether or not the NASA specifications presented to Western Union adequately described the radar interference problem. If the parties cannot come to an agreement, the issue could be decided in court. If the contractors are responsible, they will have to absorb the redesign costs. If NASA is responsible and pays for the satellite redesign, its fixed cost lease arrangement will have to be renegotiated, or alternatively, the program costs could be reduced by

the elimination of one of the two spare satellites. Whatever alternative arrangements are made will then be presented for congressional approval through the authorization and appropriations processes.

F. ISSUES CONCERNING THE SPACE SHUTTLE

1. Shuttle funding (Chapter 7)

Problems in various areas of the shuttle development program in fiscal year 1978 have increased shuttle development costs in fiscal year 1979. The appropriated fiscal year 1979 funds do not appear to NASA to be sufficient to cover the increased funding requirements. If the Office of Management and Budget (OMB) directs NASA not to request supplemental funding, how might NASA meet the increased funding needs? How much extra funding does NASA require to meet its target date of the first manned orbital flight of September 28, 1979? Will tieing the extra funding into fiscal year 1980 appropriations, as suggested by the OMB, slow down the shuttle program and make the target date unattainable? What other choices does NASA have? If there is no additional funding granted to NASA for shuttle development, what would be the cost in dollars and in the lag in various space activities dependent on the shuttle?

2. Shuttle utilization (Chapter 7)

The space transportation system (STS), as the major NASA program of the 1970's and 1980's, is an extremely costly program. The cornerstone of the STS is the reusable space shuttle which is constructed to permit many design economies in the payloads it will launch. By virtue of its reusability and the benign launch environment it promises, the space shuttle is planned to be an economical way to conduct space activities in the 1980s and to replace the use of expendable launch vehicles (ELVs).

To a very large extent, however, shuttle economies will depend on the extent of utilization of the shuttle. Is NASA doing enough with the potential non-NASA user community to interest it in shuttle utilization? Will the shuttle pricing policy affect shuttle utilization? Will sufficient paying users be found for the shuttle to be economical? Will there be some limited competition with the European Ariane launch vehicle now in development? Will the Defense Department phase out its expendable launch vehicle program with the advent of the shuttle?

3. Number of orbiters (Chapter 7)

Based on projected utilization, the Congress has authorized and appropriated funding for four shuttle orbiters, as well as long-lead items on the fifth orbiter, in order not to disrupt continuity of production. The Carter Administration, however, stated with regard to fiscal year 1979 budget that requirements for five orbiters may not materialize and that a decision on the fifth orbiter should be postponed. What would be the added costs to NASA of postponing such a decision and interrupting production? How much would new start up costs add to the price of the fifth shuttle orbiter? How would a four versus five orbiter fleet affect shuttle economics?

4. Shuttle launch sites (Chapter 7)

Two launch sites are planned by NASA for the space shuttle: Kennedy Space Center (KSC, Florida), for launches to equatorial and

low-inclination orbits and Vandenberg Air Force Base (VAFB, California) for launches into polar or high-inclination orbit. [Launch azimuths possible out of KSC range from 35 degrees to 120 degrees with a nominal payload capacity of 65,000 lbs.; out of VAFB, the range is 140 degrees to 208 degrees with a payload capacity of 45,000 lbs.] The General Accounting Office (GAO) has criticized plans to use VAFB as a shuttle launch site, saying that all necessary missions could be launched from one site, the Kennedy Space Center launch facility. NASA's position is that launches into polar or high-inclination orbit from Kennedy and landings at KSC from such orbits would involve overflight of the United States, Canada, and the Soviet Union, possibly at suborbital elevations; that launches to high-inclination orbits from KSC would have to involve lower payload weights due to necessary dogleg maneuvers to obtain the more difficult orbit from such an easterly position; and that there will be too many shuttle flights to be accommodated by one launch and landing facility.

Could polar launches from KSC be conducted safely and without possible infringement of the air space of other countries? What would be the international implications of military shuttle missions which crossed over the Soviet Union at suborbital elevations? Are the risks to populated areas acceptable with polar and high inclination launches from KSC? Could all foreseeable launches planned from both sites be scheduled out of one launch facility? Could all national defense needs be met by launches from KSC?

5. Backup capability to the Space Shuttle (Chapter 5)

The current expendable vehicles will have to remain the principal launch means until the shuttle proves in actual use its capabilities as presently projected. If expected performance and reliability are attained, then the issue of maintaining expendable rockets as a backdrop becomes significant.

There is some uncertainty today as to how many shuttle craft (up to five) will be built. The lower the number placed in service, the higher the risk is that refurbishment time between flights or accidents could leave the Nation without an immediate means to make high priority launches by shuttle, so that some other backup would have to be considered.

Small Scout launch vehicles of limited lifting capacity and large Saturn V class heavy lift vehicles (in mothballs now) probably are not competitive with the future shuttle. So the issue relates to expendable rockets in the Thor, Atlas, Titan, and Saturn IB categories.

At one extreme, could we provide for future emergency launch needs by stockpiling some of these intermediate size rockets, or will we have to go to the other extreme of maintaining active production lines and regular launches of expendable rockets in order to insure timely and reliable performance? Is there a compromise policy somewhere in between the extremes?

If we do keep such an expendable capability, how few systems of the available present rockets would suffice, and how versatile would these rockets have to be in terms of lifting capacity and orbital characteristics?

Should we continue indefinitely using a small number of these existing rockets, or should we be committing resources to new and improved

expendable rockets? Would it be cheaper and more practical to put resources into enlarging the shuttle fleet before using up any stockpile of existing expendables?

6. The next generation Space Shuttle (Chapters 5, 16)

For some years the development cost of the present shuttle has absorbed a large share of NASA resources to the detriment of other programs. On the completion of this phase of shuttle costs, there may be a great pressure to switch available funds back into payloads and missions which have been marking time. Many flights will help to spread the overhead costs of the existing investment in shuttle launch capability. But even if five shuttle craft are built, each is rated to have a life of 100 flights, and at some point they will need replacement either because of age or accidents.

Should we build more shuttles of the same design, or should we be spending new funds on advanced development for a later generation of shuttle which might offer greater operating economies than the first version?

The present shuttle was originally to have had two completely recoverable stages, but peaking problems in the budget forced a retreat to a design which now expends a part of the system, so that operating costs are about double what was once hoped for. Having reached development completion of a reusable orbiter stage, should we now commit funds to a reusable manned booster first stage?

Has knowledge of advanced materials and engineering progressed far enough that we could build an even more cost effective single stage to orbit completely reusable shuttle?

7. Propulsion requirements beyond the Shuttle (Chapter 5)

Aside from space tugs for assembly, errand running, and boosting to higher orbits beyond the reach of the shuttle orbiter, what may be the need for larger capacity transfer systems? These would be systems which do not serve to lift objects from the surface of the Earth, but might be used to build solar power stations at more remote locations, build "colonies," or explore deep space on a larger scale than has been done so far.

What are the tradeoffs of advanced chemical systems, nuclear systems, or electric systems for powering such transportation means beyond the shuttle? Many of these future systems could take a long period of time to translate from concept to operational vehicle. Is there an institutional problem that such expensive and extended time systems have difficulty being funded because they lack an approved application, and that approved applications are dependent upon a reasonable assurance that a technical capability exists or is almost ready?

Are there any new propulsion ideas worth pursuing that have not already been tested adequately, and how much money should go into concepts outside the presently orthodox and proven?

8. Space shuttle main engine (Chapter 7)

The space shuttle main engine program (SSME) has been plagued by many technical difficulties and the development has been more costly and proceeded more slowly than originally anticipated. Is the SSME program on target, technically and time-wise, for the first manned orbital flight in September 1979? If not, what remedies could NASA

employ? What are the costs to NASA of a slip in the schedule of the SSME? Will NASA require additional development funding for the SSME?

9. Patent rights from shuttle utilization (Chapter 7)

The shuttle is designed for both basic and applied research. Many investigators, both in the United States and abroad, will be conducting research on space applications using the shuttle, Spacelab, and Spacelab pallets. What will be NASA's policy regarding patent rights to marketable space technologies, processes, materials, etc., which result from shuttle utilization?

10. Teleoperator retrieval system and the Skylab revisit (Chapters 6, 7)

In 1973, the United States launched the Skylab space station, weighing 77,100 kilograms (85 tons). At that time, it was expected to remain in orbit for approximately ten years, after which it would reenter the Earth's atmosphere. During reentry much of the station is expected to disintegrate due to friction with the atmosphere, although some large pieces could survice reentry and fall back to Earth intact. Due to unexpected solar activity, which increases atmospheric drag and causes an object to reenter more quickly, Skylab is now expected to reenter sometime in 1980, although the exact month cannot be precisely determined. NASA is proposing that, using the space shuttle, an attempt be made to either reboost the space station to a higher orbit for possible reuse or to make the station come back to Earth in a controlled reentry to reduce dangers of pieces falling in populated areas.

The teleoperator retrieval system (TRS) is being developed for use with the shuttle to deliver, stabilize, and recover satellites in orbit. Its first mission is to be the Skylab revisit, but any further delays in the shuttle program may mean that Skylab will have already reentered before TRS can be launched. Funding for TRS was approved in NASA's FY79 budget. Should Congress continue to fund TRS if it appears that the Skylab mission will not be feasible? What specific uses might the TRS have other than the Skylab mission?

If Skylab is reboosted, what use can be made of the station? If it cannot be reboosted or set on a controlled reentry course, what dangers exist to the inhabited areas of Earth from falling debris (Skylab's orbit takes it over the area of Earth 50 degrees north to 50 degrees south latitude, 80 percent of which is over water)? Is there anything the United States can do to reduce those dangers?

11. Management and operation of the Space Transportation System (STS) (Chapter 7)

When the shuttle becomes operational, it will mark a transition in NASA from an R. & D. agency to one with significant shuttle operational responsibilities, if NASA retains the operational program. What are the benefits to NASA and to the STS if NASA operates it? If the Defense Department or another government agency (such as a user agency like the Department of Interior or the Department of Commerce) operates the STS? If private industry operates the system? If a semi-private organization is established specifically for operating it?

If NASA manages the STS, it may impose new organizational and management requirements within the agency. What would be the most effective organization for NASA in-house shuttle management?

12. NASA/DOD relations (Chapter 7)

NASA and the Defense Department will both be using extensively the STS. That will necessitate a high degree of cooperation between civilian and military users. Do NASA and DOD have sufficient coordination, cooperation, and communication to function together for most effective utilization of the space transportation system? What will be the NASA/Air Force interface in operating the shuttle at the Kennedy Space Center and the Vandenberg Air Force Base? How will national security considerations be taken care of while operating the shuttle as a civilian space program? How can interagency cooperation and communication be assured and implemented between these two agencies?

13. Hughes Syncom launch (Chapter 7)

The shuttle's first six flights will be orbital test flights and will test various equipment, systems, and payloads. NASA wanted to have a test spacecraft to launch on one of these orbital flight test missions. Hughes Aircraft International suggested that it provide its developmental Syncom 4 communications spacecraft (especially designed for shuttle launch) for this purpose. The original agreement between NASA and Hughes was that the spacecraft was for testing purposes only and that NASA would launch it free of charge as part of the OFT program.

Several State and Federal governmental agencies became aware of this arrangement and proposed that the Syncom 4 carry a useful communications payload instead of being solely a design-verification test. This has raised several institutional and funding questions. Who should pay for the added communications capability? Would the free launch and non-competitive arrangement give Hughes an unfair advantage? If there was an open competition for shuttle-launched communications demonstration payload would that be fair to Hughes who originated the concept of the Syncom 4? How might this problem be equitably resolved and still have the spacecraft carry a useful payload?

14. Spacelab barter agreement (Chapter 7)

The Spacelab (SL) is a space laboratory consisting of a shirt-sleeve environment of modules and pallets to be used in the cargo bay of the space shuttle. In the NASA/European Space Research Organization (ESRO) Spacelab Memorandum of Understanding of 1973, ESRO (now called the European Space Agency or ESA) agreed to design, develop, and manufacture one Spacelab module for NASA free of charge. NASA, in turn, agreed to the purchase of a second Spacelab module and support equipment from ESRO. The ESA Spacelab module is nearing completion and the United States is trying to arrange for the purchase of the second Spacelab module without significant exchange of funds. One possible method would be the exchange of four free shuttle launches for provision of the second SL module free of charge—the so-called "Spacelab Barter Agreement." It appears that

some European nations are not ready to commit themselves to four shuttle launches and so the barter agreement might not be viable. How much would outright purchase of the module cost the United States? If Congress were to deny this funding, how else might NASA meet its agreement to purchase the Spacelab module? What other types of no-exchange-of-funds agreements might there be? Might some effort be made to help Europe "sell" excess space on the four shuttle launches if Europe could not fully utilize the total shuttle capacity, thus ensuring Europe would not take a financial loss?

G. ISSUES CONCERNING THE SPACE SCIENCES

NASA's charter calls for the agency to expand human knowledge about space, and to this end, NASA has conducted a wide variety of unmanned space science missions, ranging from earth-orbital scientific satellites concerned with astronomy and solar observations, to deep space probes to Jupiter and beyond. The most spectacular of these missions was the 1976 Mars landing of two spacecraft, Vikings 1 and 2. which sent back the first pictures of the surface of that planet, and conducted experiments to determine the composition of Martian soil and search for evidence of life on Mars.

1. Types of probes (Chapter 9)

Can unmanned space science probes accomplish the same goals as manned missions in the exploration of the Moon and planets? Can the more inexpensive flyby and orbiter missions provide adequate information about the planets, or are landers such as Viking also required? Should the next mission to Mars be another lander, this time perhaps with the capability of movement on the surface? Should the United States attempt to return a sample of Martian soil to Earth for analysis? Is there a danger of contamination of the Earth if this latter option is chosen?

2. Necessity for space science missions now (Chapter 9)

Given Federal budget constraints and the fact that space will always be available for exploration, are space science missions an unaffordable luxury? Should such exploration wait until a time when spending priorities will more easily accommodate such research? What would be the effect of reduced funding for space science missions on the space science community? Without continued funding for such programs, will expertise in these areas die out?

How useful is the information obtained about other planets to life on Earth? How likely is it that we might learn something about planetary evolution that could substantially affect the manner in which humans now treat their own planet, Earth? If such information is very relevant to Earth, is that a compelling reason to continue planetary research?

3. Priority of space science within NASA (Chapter 9)

For the past several years, NASA's budget has been laden with the demands of the space shuttle. Now that the space shuttle development program is nearing completion, a larger percentage of NASA's budget should be available to conduct the other missions of the agency. Should NASA's budget remain at approximately the same level, with space science receiving a larger share of that budget, proportional with

applications and other projects, or should NASA's total budget simply be reduced with space science funding remaining at essentially its present level? Has the space science program suffered as a result of the large funding needed for the shuttle?

4. Coordination between NASA and NSF (Chapter 9)

While NASA has responsibility for space-based astronomy programs, the National Science Foundation has jurisdiction over ground-based astronomy. Despite the seemingly clear differentiation between the roles of the two agencies, some overlaps, such as the construction of the ground-based astronomy facility at Manua Kea, Hawaii, by NASA, do occur. How much overlap is there between NASA and NSF astronomy programs? Are steps being taken to ensure that the programs are not redundant? Are there programs within NASA that are more properly the function of NSF, and vice versa?

5. Lunar sample analysis program (Chapter 9)

The Apollo lunar landing program cost approximately $25 billion. One of the reasons for conducting the program was to obtain samples of the lunar surface for scientific examination on Earth to determine the nature of the Moon and its history. Approximately $41 million has already been spent studying the 381.7 kilograms (841.6 lbs.) of lunar material returned by the Apollo crews, and NASA requested $5.7 million in fiscal year 1979 to continue this research. Congress denied all but $1 million of this request, stating that such research is more correctly the province of the National Science Foundation.

Should NASA continue to fund analysis of the lunar samples or should the program be transferred to NSF, which has jurisdiction over geological programs? Does NSF want the program transferred there? What would be the impact on the program if it were transferred to NSF where it would have to compete for funding with a large variety of other geological studies?

H. ISSUES CONCERNING THE SPACE LIFE SCIENCES

Space life sciences research is in large measure the domain of the National Aeronautics and Space Administration. A comparatively smaller effort is supported by the Department of Defense. The objectives of the NASA effort in this field are to provide the Agency with basic and applied research and development to assure the medical safety, well-being and life-support of all humans involved in space flight; and to advance basic knowledge and develop applications of space technology to Earth-bound medical and biological problems by conducting investigations in space.

Since the 1960s, the space life sciences budget in NASA has declined precipitously both in terms of purchasing power and in terms of funding available for extramural research, particularly basic research. Only recently has this trend enjoyed a moderate reversal. At the same time, since the termination of the Skylab program in 1974, there have been no domestic spacecraft available on which to conduct space life sciences research. Accordingly, between Skylab and the Space Shuttle/Spacelab program planned for initiation in 1980, a hiatus of about six years will have passed during which all United States space life sciences experiments will have been flown

in unmanned Soviet Kosmos-series biosatellites. Thus, both in terms of real-time flight availability for space life sciences experimentation and in terms of funding available for such research, the issue of whether the program is adequate enough to achieve its stated objectives is a debatable one. The following specific subsidiary issues might be considered in such a debate.

1. Adequacy of funding (Chapter 8)

Precipitous increases and decreases in funding for the basic biomedical sciences related to the space environment have imposed hardships both on NASA decision-makers and administrators and on the biomedical research community. The extramural community has been the most severely affected by this trend and many of the resources in universities and industry which NASA had relied upon for the successful fulfillment of its space life sciences missions in the past have been terminated. One basic issue associated with this trend is whether the level of funding for the basic sciences is even barely adequate to support the stated objectives of the overall program, namely, the support of manned space activities.

2. Stability of funding (Chapter 8)

A correlary issue is the unstable and unpredictable nature of funding for the basic space life sciences in terms of research and development continuity and efficiency. Would the biomedical research and development community be more responsive to NASA's needs were more stable and, moreover, multiyear funding available? How severely have the capabilities of the biomedical research community been affected by unstable funding?

3. Jurisdiction (Chapter 8)

There is an issue related both to funding and subject jurisdiction: At present, NASA has virtually sole jurisdiction over the space life sciences. Given the historically unstable and unpredictable nature of funding for the space life sciences, would it be desirable to diffuse funding authority for the space life sciences throughout other funding agencies such as as the National Science Foundation, the Smithsonian Institution, the Department of Health, Education, and Welfare, the Environmental Protection Agency, or the Department of Energy? How many research proposals in the space life sciences with merit have not received funding from NASA in the past and how many of the 360 proposals thus far received for spacelab/shuttle experiments will have to be turned away due to inadequate funding?

4. Real-time flight availability (Chapter 8)

Real-time flight availability on spacecraft manufactured in the United States is another issue of concern. To some extent, this problem has been ameliorated through cooperation with the Soviet Union, as a result of which United States space life sciences experiments have been flown on two unmanned Soviet Kosmos biosatellites. Have these experiments been adequate for NASA's needs? Have they been cost effective? How has the lack of real-time flight availability affected progress in the space life sciences? Will upcoming spacelab/shuttle programs serve to compensate for past hiatuses of space inactivity?

5. Future manned space activities (Chapter 8)

Finally, there is the issue of future manned space activities. Is funding for the space life sciences, particularly the basic biomedical sciences, adequate to keep pace with technological advances which seem likely to render the space environment more accessible to man within the next 25 years? As the space environment becomes more accessible to man, will he be biomedically prepared to take advantage of that accessibility?

I. ISSUES CONCERNING MATERIALS PROCESSING IN SPACE

The concept of materials processing in space centers on the fact that in space, such procedures can be accomplished without interaction of the force of gravity, which is ever present on Earth (even in vacuum chambers). The lack of gravity would permit production of, for example, certain metal alloys which cannot be produced on Earth because the metals being combined have different densities and therefore settle into a layered pattern, rather than mixing into one homogenous material. In space, without gravity, the metals would mix into a homogenous material and might produce superior materials such as superconductors.

1. Industry-wide survey (Chapter 11)

The ultimate success of materials processing in space may depend to a large extent on whether or not industry will be interested in the new procedures and products stemming from work in the near-zero gravity environment of space. U.S. industry is traditionally reluctant to invest in programs which require significant expenditures of money prior to proof that the program or product will be profitable.

Should a study be made to assess U.S. industry's interest in space manufacturing prior to approval of Federal expenditures for initial research and development in this area? Are there incentives which might be provided to industry (such as tax incentives) to increase their interest in space manufacturing at this early stage of development? Should a survey also be conducted of foreign industry to determine its interest in the field? If industry is not interested, should that fact foreclose government research in the field, or should such research be conducted regardless of industry interest at this stage?

2. Space industrialization trust fund (Chapter 11)

In September 1977, Sherwood Fawcett, President of Battelle Memorial Institute, suggested in hearings before the House Committee on Science and Technology, that a space industrialization trust fund be established to provide money for space processing experiments. The money would be available for innovative experiments, and if a marketable product emerges from the research, certain royalties would be levied against the parent company and the money returned to the fund. What are the barriers to establishing such a fund? Who would operate the fund—the government, a quasi-governmental agency, a public corporation, or industry itself?

3. Proper role for NASA in space processing program (Chapter 11)

Has NASA been providing adequate preflight support to experimenters who require substantial Earth-based knowledge about the

behavior of materials before flying their experiments in space, such as in the SPAR program? How much funding should NASA provide for a space processing program at this time before its economic viability has been established? That is, should industry and the university community be asked to pay for this research and development since they are the ultimate beneficiaries of the results? Has NASA heeded the advice of the National Academy of Sciences Space Applications Board in their report "Materials Processing in Space" in terms of the organization and direction of the materials processing in the space program?

J. ISSUES CONCERNING INTERNATIONAL SPACE PROGRAMS

Since the inception of the U.S. space program, the United States has been active in cooperating with other countries in space research and applications. The areas of cooperation are quite broad, including ground-based observations using NASA satellites, launching of other countries' satellites, carrying experiments from other countries on NASA spacecraft, and disseminating information and data gathered by U.S. meteorological and Earth resources satellites.

Although the Soviet Union is America's main competitor in space exploration, there has also been U.S.-Soviet cooperation. Four agreements have been signed to facilitate this cooperation, one which led to the Apollo-Soyuz Test Project (ASTP) mission in which three American astronauts in an Apollo spacecraft docked with a Russian Soyuz spacecraft carrying two cosmonauts. During preparations for the mission, both crews had opportunities to visit the other country's space centers and examine space hardware—the first time such opportunities had occurred.

1. Effectiveness of cooperation with U.S.S.R. (Chapter 12)

How effective has U.S. cooperation been with the Soviet Union in the past, and what are the prospects for the future? What barriers exist to expanded cooperation with the Soviet Union? During ASTP, did the United States give away substantial amounts of technological knowledge without gaining similar knowledge from the Russians? Were there intangible benefits, for example in the foreign policy arena, which made the missions worthwhile in and of themselves? Should there be future cooperative manned missions between these two countries?

2. Benefits of international space cooperation (Chapter 12)

Is the United States, and especially NASA, doing all it can to foster international space cooperation? Is such cooperation beneficial enough to the United States, either economically or in terms of foreign policy and international good will, to make it worthwhile?

3. Technology export decisions (Chapter 13)

Export of technologies which have direct or possible indirect military application is prohibited. The Munitions Board of the State Department maintains oversight of such technologies and has a list of proscribed technologies. Many technologies relating to space are on that list, and many people believe that some technologies are listed unnecessarily and that the list limits aerospace exports needlessly.

What agencies are involved, officially or unofficially, in making space technology export decisions other than the Department of State? How could the decision-making process be streamlined? The Departments of Defense and Commerce are reevaluating their critical technologies list in order to see if some technologies may be removed from it. Should the State Department Munitions Board list likewise be re-evaluated with a view toward allowing export of more space technologies which are not directly munitions-related? Is the United States' policy with regard to space technology transfer equitable to all countries, or do some receive favored treatment, as in the sale to Japan of Delta launch vehicle technology that was denied to the European Space Agency?

4. Launch assurances (Chapters 10, 12)

Should the United States guarantee to launch other countries' satellites regardless of their mission? Should we launch applications satellites even if they might prove economically competitive with U.S. sponsored systems such as Intelsat?

The non-competition clause in Intelsat's charter requires that Intelsat members consult with Intelsat prior to establishing, acquiring, or utilizing space communications satellites separate from Intelsat to: 1) ensure technical compatibility of such facilities and their operation with the use of the radio frequency spectrum and orbital space planned for Intelsat, and 2) avoid significant economic harm to Intelsat. U.S. practice pursuant to this clause has been that it will not launch a communications satellite which might cause significant economic harm to Intelsat. However, if the United States refuses to launch communications satellites for other nations on the grounds that such satellites might compete with Intelsat, how will this impact on U.S. foreign relations? Would such refusals serve as an additional impetus to development of alternative launch capabilities? How will the United States resolve its national position regarding the non-competition clause in Intelsat's charter? In the interests of international good will, could the United States launch satellites which might be detrimental to Intelsat's economic interests?

5. Non-Government foreign policy in satellite communications (Chapter 10)

Emphasizing the need for technical expediency in the establishment of a global satellite communications network, the United States entrusted certain aspects of its foreign relations in the area of space communications in part to the profit-oriented business community, specifically, Communications Satellite Corporation (Comsat), which is privately-funded but has a mixed private-public board of directors. Should technical expediency and commercial profit continue to be our primary goals in the exploitation of space communications tehnology? How do these goals affect U.S. foreign relations? Can international political considerations be taken into account in the formation of an international organization to develop a technology without delays in the implementation of that technology? Are technical expediency and commercial profit incompatible with international diplomatic considerations? If so, how can possible conflicts be resolved?

Should the United States, through Intelsat, promote coordination and implementation of economic and political goals such as free chan-

nels for development-oriented programs, subsidization of space industries in European nations, or earth stations and an Intelsat membership for every country regardless of traffic level and/or ability to pay?

6. International implications of remote sensing technology (Chapter 10)

In addition to institutional and operational aspects of remote sensing, there are international issues which have arisen from the nature of the technology. In general, the United States has always insisted upon open dissemination of data obtained from civilian space activity. However, the nature and uses of remote sensing data give rise to fears that such data might be abused. For example, data from remote sensing might be used by one nation for strategic, political, or economic purposes which are not in accordance with the desires of the nation which the data concerns. To some nations, the possibility exists that gathering and using remote sensing data might pose a conflict with national sovereignty.

How can the United States reconcile the questions of national sovereignty and control over space activities with most effective functioning of the system? As the system evolves from experimental to operational status, many nations believe that data gathering by the space segment of the Landsat system should not be subject to rules of national sovereignty while data use through the ground segment should be. How might this affect the conduct of the Landsat program? What is the United States doing to safeguard the information gathered about other countries? Is this effective? How is controlling the use of data gathered on other nations through remote sensing reconciled with the U.S. policy on open dissemination of data?

7. Foreign space launch systems (Chapter 5)

Foreign launch systems may compete economically with the United States space shuttle. By dividing the market, both the shuttle and the foreign systems might not have enough business to maintain their economic health, but having foreign launch systems available also would be a way to provide emergency backup for U.S. launches if shuttles are not available.

The European Space Agency is in the final stages of developing the Ariane expendable launch system, which will compete with the shuttle for payloads. Should the United States support this project with its technology, or be its customer? Will successful development of the Ariane lead to even stronger competition for the shuttle through future, more advanced European systems?

Is there potential international competition to be expected from the Japanese or Chinese launch systems now developing or planned, and what should be the U.S. posture on technology transfer in this regard?

There is a German-French private and commercial launch system (OTRAG) being developed for launches from Zaire in Africa. The design approach is to cluster large numbers of very simple rockets. What should be the U.S. position with regard to this effort?

The Soviet Union has the only other fully developed, comprehensive space program. Will that country compete increasingly for international business? Do they have a reusable shuttle of their own, and how competitive could it prove to be?

K. ISSUE CONCERNING DOMESTIC TECHNOLOGY UTILIZATION

Because the benefits of the space program are multiplied many times as space technology and data are put to work in the user community, space technology has been of benefit in numerous fields, including many totally unrelated to the space program. How can NASA strengthen its ties to the space technology user community to ensure greater utilization of space technology? How might NASA and other Federal agencies stimulate domestic technology utilization? Should the NASA budget include funding for marketing aid from the private sector to enable NASA to best capitalize on the Nation's space investment? Does NASA need better communication with the users of space technology and better in-house capability to work with users and serve their needs? Should NASA take more initiative in defining user needs and ways to meet them? Could, and should, NASA stimulate use of remote sensing data inside and outside of Government? (Chapter 15)

L. ISSUE CONCERNING NASA UNIVERSITY SUPPORT

The Federal Grant and Cooperative Agreement Act of 1977 (Public Law 95–224) stipulates that all Federal agencies, in transactions with non-Federal parties, distinguish between "procurement," which is buying something for the Federal Government's direct use, and "assistance," which is supporting or stimulating a non-Federal activity in the public interest. NASA's policy has been that it does not provide assistance to universities; rather, the money which goes to university research is buying something, i.e., research, for NASA's direct use. Although formerly NASA used more broadly-defined grants in its relationship with universities, under the terms of the new Federal Grant and Cooperative Agreement Act, the NASA/university relationship will have to be one of procurement of services through contracting procedures.

NASA must therefore establish and implement a workable, efficient, and hopefully, streamlined procedure to contract for services from universities. Will compliance with the provisions of Public Law 95–224 cause significant changes in NASA's university research program management? What costs will accrue to NASA to handle its university research program through contracting procedures? Will this create the need for more personnel to administer the contracts program or create additional management levels? (Chapter 14).

CHAPTER THREE

HISTORY OF NASA AND ITS RELATIONSHIP TO UNITED STATES SPACE POLICY

By George N. Chatham
Specialist in Aeronautics and Space

I. NACA Is Formed in 1915

The National Aeronautics and Space Administration (NASA), was preceded by the National Advisory Committee on Aeronautics (NACA). The NACA had 43 years of life before evolving into the NASA and passed on much of its philosophy and policies. An understanding of the NACA greatly simplifies an understanding of NASA and its policies.

Senator Ben Tillman and Congressman Ernest H. Roberts introduced the joint resolution to establish NACA, but despite the favorable committee report and administration support, it appeared that adjournment, scheduled for March 4, 1915, would allow the resolution to die. There was sufficient time to tie the NACA enabling legislation to the Naval Appropriations Bill as a rider. In this form, the NACA bill was signed by President Wilson on March 3, 1915, with an appropriation of $5,000 for the first year of operation.

Twelve presidentially appointed non-paid members from the Government and the civil scientific community were "to supervise and direct the scientific study of the problems of flight, with a view of their practical solution," and to "direct and conduct research and experiments in aeronautics." All members, even of the later technical subcommittee, served without compensation except for travel expenses.

A. A PHILOSOPHY EMERGES

An early concern, voiced by Franklin D. Roosevelt when he was Assistant Secretary of the Navy under President Wilson and approved the concept of forming an advisory committee for aeronautics, was that civil interests might evolve to dominate the committee at the expense of Government (military) objectives. He recommended changes in membership which would retain for the Government a "controlling interest in the activities of this proposed committee."[1]

The NACA committee, on the other hand, had always envisioned a far more elementary role, that there would be no effort to aid the military or the civil industry in a game of "catch-up," except as the revelation of fundamental principles, ". . . to increase the safety and effectiveness of aerial locomotion for the purposes of commerce, na-

[1] Franklin D. Roosevelt to L. P. Padgett, Feb. 12, 1915. In U.S. Congress. House. Committee on Naval Affairs. Hearings. 63d Cong., 3d sess., 1915, pp. 1267–68.

tional defense, and the welfare of man," [2] may be applied by others in the pursuit of "catching up."

Coupled to this resolve to remain academic was an equally powerful commitment that no researcher's work should be directed. Requests for research would be considered, but assignments, regardless of origin, could not be made. This high degree of autonomy was a source of strong irritation to the military. In the early days of the Langley laboratory, the NACA people became such an anathema to the military that a concerted effort was made to make them vacate the premises. In General Billy Mitchell's words:

> It is difficult to handle this National Advisory Committee in any way. It (the NACA) does no good here nor any other place that I can see and there is a project of law now for its abolishment which I hope will take place.[3]

However, deep concern over the prospect of United States participation in a war with Germany swept through the military and also through the NACA. In 1936, the joint Army-Navy Aeronautical Board reached the conclusion that in the event of war, NACA should give up its independence and place itself under the direction of the Board. Shortly thereafter, a special NACA subcommittee convened by Chairman Ames, agreed with this viewpoint.[4]

During the war years, 1941–1945, NACA efforts were almost totally in applied technology. New fighter aircraft began to appear and essential changes to increase their speed, indeed to make them reasonably safe to fly, placed a double and sometimes triple shift of work load on the NACA Centers.

Following the war, the NACA returned to a more orderly routine but found an equally great, although quite different, challenge and responsibility. Its own bank of basic research, built up during the 1920's and early 1930's, had been exhausted in the early war years. With peace, the NACA had become heir to large quantities of more advanced German research, not only in aeronautics but also in propulsion and rocketry.

In the mid-1950's, as part of the U.S. participation in the forthcoming International Geophysical Year, a small satellite was to be placed in Earth orbit. After a spirited competition for permission to build a satellite between the Naval Research Laboratory (Vanguard) and the Army-Jet Propulsion Laboratory (Explorer), the N.R.L. was chosen in September 1955. In President Eisenhower's view, Vanguard would not conflict with high priority military missile programs, and better project a peaceful image. During 1957 the Vanguard team was preparing its first test vehicle for firing.

However, on October 4, 1957, a Russian satellite, Sputnik I, 60 times as large as the 1.4 kilogram test Vanguard, began sending signals to Earth from orbit. The Soviet Union had orbited the world's first artificial satellite. It was followed a month later by Sputnik II, a 500 kilogram satellite, carrying a dog as a passenger.

The decade of cold war with the Soviets had suddenly produced a national chill. It would be difficult to imagine a more visible demonstra-

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[2] "Advisory Committee on the Langley Aerodynamical Laboratory." Smithsonian Miscellaneous Collections, vol. 62, No. 1 (July 17, 1913–14).

[3] William Mitchell to T. B. Mott, Apr. 22, 1920. Correspondence 1920, Box 8, Mitchell Papers. Mitchell's "project of law" was confined to the military.

[4] NACA Minutes, Oct. 22, 1936; NACA Executive Committee Minutes, Feb. 11, 1937.

tion of technological prowess than these two "massive" satellites announcing their presence by radio every few hours.

On December 6, 1957, the hopes that Vanguard would signal the presence of the United States in space were dashed as its launch vehicle exploded on the pad. Plans for the competing program, the Army Ballistic Missile Agency—Jet Propulsion Laboratory (ABMA–JPL) Explorer, were reinstated and on January 31, 1958, the 14 kilogram Explorer was placed in orbit.

It was a light-weight response to the large Russian satellites, but hopefully indicated to the world that the United States was at least aware of the space domain. It did not lessen the public concern, nor the anxiety of Congress, however. Should the Russian triumph be acknowledged as a superb bit of military one-upmanship? How could this be avoided? How could the United States accept this situation with a minimum loss of prestige? There was an answer.

During a decade of cold war maneuvers with the Russians, the war had remained cold. That is, there were no direct military confrontations, and for all public records the ultimate goal of both sides in a cold war is peace. The Eisenhower administration therefore declared the United States view that outer space should be used only for peaceful purposes.[5] The Nation would thus be removed from an arena of military competition in space and, with efforts to get the Russians to concur in this philosophy, space would become a domain of international cooperation.

Of course, the Sputniks had their origin in Russian military programs, but they were peaceful. It would not be a denial of the peace-in-space philosophy for the United States to continue using the only hardware it possessed, namely military hardware, to launch additional satellites while it endeavored to establish a civilian space program.

B. THE FIRST U.S. SPACE AGENCY

Shortly after Sputnik, Eisenhower had given interim responsibility for the U.S. space program to the Defense Department. In February 1958, Congress authorized Defense to establish the Advanced Research Projects Agency (ARPA). In March, Eisenhower gave his approval to an interim plan for space exploration which had been advanced by ARPA. Thus, in a genuine sense, the first U.S. space agency was a military organization, ARPA.

C. THE NACA PLAN

Although a number of plans for a civil space agency were advanced in Congress, some as bills, the administration and most legislators favored giving the well established and highly regarded NACA full responsibility. The urgency, still strongly felt in the Federal as well as the private sector, simply would not allow the time needed to start a totally new agency.[6]

NACA leaders, firmly convinced of the superiority of their own committee structure, proposed that their board be enlarged to 17 members;

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[5] Arthur Levine. U.S. Aeronautical Research Policy 1915–55, Doctoral Dissertation, Columbia University, 1965, NASA Library.

[6] Levine, op. cit., p. 151.

their name changed to the "National Advisory Committee for Aeronautics and Astronautics," and their role and responsibility remain one of research and assistance to "user" agencies and civil groups.

The NACA felt confident that the new space flight research responsibility would be assigned to them. In November 1957, the NACA chairman, Lt. General James H. Doolittle, approved the main committee establishment of a new Special Committee on Space Technology to be headed by H. Guyford Stever. Branching down from the new committee, a group of new subcommittees were to be formed, each to handle "special aspects" of space challenge.

In their bid for this new role, the main committee had met in January 1958 and on January 16, published a new resolution on space flight.[7]

The resolution was carefully worded but subject to differing interpretations. Statements were included in which the NACA traditional role would be greatly enlarged to include "... Design and development of scientific and military space vehicles and their launching, flight and recovery." However, in later paragraphs, responsibility for the various types of vehicles was "resolved" to be the responsibility of the user agencies. The total thrust of the resolution seemed to suggest a view that the space effort on the part of NACA would be the conduct and coordination of a larger but parallel program patterned after the successful "X" series of experimental aircraft.

Eisenhower and his advisors, especially his newly appointed Science Advisor, Dr. James R. Killian, acting from the conviction that the new space agency should be a civil, or at least a nonmilitary effort, strongly favored turning the responsibility over to the NACA. However, there was a problem or two. First, the committee structure of the NACA did indeed "report to the President" but it was not obligated to him too closely. During its history the NACA had shown itself to be rather refractory to political leadership. There was a question as to whether or not an issue as politically volatile as the new space venture should be relegated to a rather independent committee.

Second, the NACA tradition had established its character as more academic than executive. Research, regardless of the quality and responsiveness to the problems of users, did not seem an adequate substitute for executive action and primary responsibilities.

The skills and facilities of the NACA in aeronautics were without equal in the Nation, but something more was needed.

II. The National Aeronautics and Space Administration (NASA) Emerges From the National Advisory Committee on Aeronautics (NACA)

Early in 1958, Eisenhower asked his science advisor, Dr. James R. Killian, Jr., to formulate a plan leading to an adequate civil space agency. Killian, in conjunction with experts in administrative organization, such as William M. Finan of the Bureau of the Budget, submitted a recommendation to Congress in the form of a draft bill on April 4, 1958.

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[7] Reproduced in total in the National Space Program, Report of the Select Committee on Astronautics and Space Exploration May 12, 1958, 85th Cong., 2d sess., House Report 1758.

As with all new things in a political setting, there were many views and arguments both within and outside the Congress on the proper way to establish a national space effort. Surprisingly only two issues appeared to have critical importance:

1. The extent to which the new agency was to have its own authority to develop and operate vehicles in space over and above its research and consulting functions.
2. What was to be the scale of its operations.

A third issue, that of military vs. civil control, was not controversial at this period. "On the desirability of ultimate civilian control, virtually all witnesses were agreed, the military men conspicuously so." [8]

The ready acceptance of civilian leadership, when in fact it had been the military programs, not civilian ones, which had contributed all that was significant up to this date, is more understandable when the consideration is made that "90% of the NACA work was done either directly for the military or through military contractors." [9] In this sense, the NACA was a civilian research and consulting arm of the military. Perhaps, having the national space effort under the NACA control did not seem too great a loss.

The administration bill changed the structure of the advisory committee into that of an agency with the NACA as a nucleus. It was not to be considered in any way an enlargement of the old NACA. The changes, over the strong protest of the NACA, were for the purpose of establishing not only a single responsible executive but also to insure that ". . . it would be a powerful operating agency . . . with significant authority for contracting for the building of "hardware" and for systems development, for launching satellites and other space vehicles, and for the transfer or use of other Government facilities that could contribute to the space program." [10]

The NACA leadership saw this as directly opposite to their own plans and opposite to their traditional method of operating. The head of the agency would be on the front line of the political arena. There would be no committee structure to isolate him from "politics." Moreover, the space agency was to have total responsibility for the civil space program in lieu of the division of this responsibility among the user agencies, science agencies and the military, which NACA desired.

There remained a question as to whether or not such enormous executive responsibility could reasonably be placed on an organization, whose operating traditions for 43 years has all been consultative, advisory and mediatory. As NACA Chairman, Dr. Hugh L. Dryden noted in his testimony,[11] "We stand ready to consult with industry in technical matters. We have not told people what to do."

The NACA leadership understood that the Administration, and the rapidly mounting support for a space agency in both Houses of Congress, wanted an agency with strong operational initiative and operational authority. Had the desire been otherwise, their own plan to enlarge but preserve the function and philosophy of the NACA would have been accepted.

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[8] The National Space Program, op. cit., p. 7.
[9] The National Space Program, op. cit., p. 13.
[10] Levine op. cit., p. 156.
[11] The National Space Program, op. cit., p. 13.

It was considered a significant [12] change, for example, when in the "Declaration of Policy" the space agency (to be called the National Aeronautics and Space Administration) was given responsibility for "aeronautical and space *activities* sponsored by the United States . . . ," the word "activities" being substituted for the word "research."

A. SCALE OF OPERATIONS

The full scope of operations envisioned by Congress and fully described in the House committee report [13] was not to be fully realized in the Eisenhower Administration. Congress had deleted the word "agency" in the NASA title and substituted the word "administration," sharply scaling up the importance and (hoped for) operational pace and power of the new organization.

The NACA personnel had hoped and assumed that Dryden, with his staunch faith in the correctness of the NACA philosophy, would be subsequently the first Administrator of NASA. Dryden was held in high esteem by Congress, but as a scientist, and a conservative one at that. After all, he had testified that his view of the Air Force's project Mercury, soon to be inherited by NASA, was a circus stunt, "like shooting a lady out of a cannon." [14]

An aggressive leader, Dr. T. Keith Glennan, President of Case Institute of Technology and former Commissioner of the Atomic Energy Commission was nominated by Eisenhower and quickly confirmed by the Senate. Glennan was sworn in on August 19, 1958 with Dryden as his deputy. Then, on October 1, 1958, NASA came into existence. While still in the process of integrating the facilities transferred to NASA by the Space Act, Glennan took his turn to explain the NASA role to Congress in July 1959. To their dismay, they heard Glennan say:

> Basically we are a research, development and exploration group . . . Now we do not conceive our job as taking us into operational systems, but perhaps to the prototype . . . but not beyond that . . .

Gibney observed:

> This was hardly the sort of big thinking that Congress was quite plainly hoping for. The 1958 space law stated clearly that NASA should direct "space activities" of the United States except for . . . weapons development.[15]

The scale of operation, envisioned by Congress was an aggressive national effort in which the goal was to regain supremacy of space achievement from Russia, and the dollar cost to be considered a secondary matter. This was a political, more than a scientific objective and it required the establishment of a political goal. This goal was supplied by President John F. Kennedy on May 26, 1961, when he announced:

> I believe that this Nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth.

Kennedy had already replaced Glennan with James E. Webb, a vigorous and politically wise administrator who was prepared to carry out the lunar commitment. The effect on NASA was dynamic. Its central corps, still operating with the studied and independent pace so long

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[12] Levine, op. cit., p. 173.
[13] The National Space Program, op. cit.
[14] The Reluctant Space Farers, Frank Gibney and George Feldman, Signet, New York, 1965, p. 80.
[15] The Reluctant Space-Farers, op. cit., p. 79.

protected by the NACA philosophy of autonomous function, found itself committed to a major national effort, one which required intense central direction.

B. NASA INHERITS CENTERS FROM THE MILITARY AND ESTABLISHES NEW CENTERS

Under Glennan, NASA obtained the Jet Propulsion Laboratory (JPL), a Government owned facility managed by the California Institute of Technology, on December 31, 1958. The space portion of the Army Ballistic Missile Agency, Huntsville, Alabama (later called Marshall Space Flight Center), under Wernher von Braun, as well as the Naval Research Laboratory Vanguard team, were transferred to NASA on March 15, 1960.

NASA quickly concluded that the work, primarily research, underway at its formerly NACA centers (Langley, Lewis and Ames) was essential and not to be cancelled or even redirected to any major extent by headquarters. New and dedicated centers were established for the conduct of the national goal to land on the lunar surface and return before 1970. NASA constructed a launching facility at Cape Canaveral (later renamed Cape Kennedy), and automated (unmanned) spacecraft control and research center, the Goddard Space Flight Center at Greenbelt, Maryland, a manned mission control center, the Manned Space Flight Center (later Johnson Space Flight Center) near Houston, Texas, a rocket and test facility in Mississippi (the National Space Testing Laboratory, NSTL) with an associated assembly facility at Michoud, Louisiana as well as a number of smaller support facilities in several States.

Even with the remarkably rapid build-up of NASA's capability, work in the private sector expanded even more rapidly, absorbing over 90% of the NASA budget.

In this expansion, NASA's public policy suddenly became the reverse of the NACA. The new technology emerging from the space venture would not be bound to a Government center housing the advanced equipment and expertness of Government research scientists. By virtue of development contracts, the new technology would be within the private sector automatically.

Programs of technology transfer were also established to make accessible to the private sector the still considerable amount of research results generated within the NASA Centers.

Although the goal to reach the moon before 1970 was to large extent the fulfillment of campaign pledges to see that the United States restored its prestige in space, a political goal, NASA conducted its exploitation of the space domain from as broad a perspective as it could, short of risking an unacceptable delay in the lunar flight. A variety of earth surveillance satellites, the earliest being meteorological, were developed. Satellites for communication were developed and spun-off to private enterprise. Automated satellites and probes were employed to do lunar and planetary surveys, astrophysical studies and experiments in the biological sciences.

The total space effort, however, had drawn funds as well as personnel away from aeronautics research. By 1965, as the space competition with Russia was reaching its climax, the feverish enthusiasm in Con-

gress had already begun to lessen. The Senate Committee on Aeronautical and Space Sciences initiated an intensive series of hearings on aeronautics. The NASA slow down in aeronautics was identified as a new area of technological lag.[16]

As the Apollo mission preparations grew more intense, the pressure on NASA increased to identify post lunar goals. The lunar flights, it seemed, were becoming anticlimatic before the fact. NASA budgets began to decline after 1965, clearly signaling the end of the era of intense political concern over the Russian space successes.

In 1968, the Apollo-Saturn system had proven itself in earth orbit, and, except for the Lunar Module (LM), was ready for the lunar mission. The LM was not expected to be ready until 1969. However, a series of Russian magazine pictures and news stories as well as conversations with Russian cosmonauts gave the strong impression that Russia was about to initiate a lunar orbital mission. There was less indication that a landing was contemplated. However, it seemed that if the lunar mission was delayed until the lander was ready, the United States could lose this final race.

To circumvent this, NASA decided to send Apollo 8 into a lunar orbit without the LM. Apollo 8 was launched on December 21, 1968, and succeeded in its mission without difficulty.

The subsequent Apollo missions with the LM and the successful landing on the lunar surface were anticlimatic to the Apollo 8 mission. A Russian duplication of the Apollo 8 would be of dubious prestige value if successful, and extremely negative if it failed. There was no successful Russian attempt and the race to the moon was a clear victory at this point.

Tests of the LM on Apollo 9 and 10, followed by lunar landings beginning with Apollo 11 (July 20, 1969) and continued through Apollo 17 (December 7, 1972). All were successful with the exception of Apollo 13 which was disabled by the explosion of an oxygen tank. Apollo 13 circumnavigated the moon and returned safely but did not send its LM to the lunar surface.

III. Post-Apollo Planning

During the most intense period of the Apollo flights, NASA was under pressure to propose and plan post-Apollo activities. During 1965, NASA conducted a planning session called the Woods Hole Conference. A broad spectrum of the science community participated and over 150 worthy program candidates were identified.

The urgency felt in NASA was shared by their contractors who faced massive shutdowns and the dispersal of many expert teams of engineers. NASA was asked to produce scientific programs attractive enough to sustain an effort which had been elevated by a national fervor. The task proved too much and after 1965, the NASA budget began a steady decline.

Webb, discouraged over the decline of NASA, resigned in 1968. He was replaced by Thomas O. Paine. During Paine's tenure, NASA's decline began to reach heavily into its personnel. A series of reductions-inforce began and morale at NASA began to reflect its steady decline.

[16] Policy Planning for Aeronautical Research and Development, 89th Cong., 2d sess. Senate Document 90, May 19, 1966.

IV. A New Space Transportation System (the Shuttle) Emerges

As the hardware residuals of the Apollo program were being expended to conduct Skylab (1973–74) and Apollo-Soyuz (1975), intensive planning for a new space transportation system was underway. NASA had felt from the beginning of the space race that the expendable boosters, extrapolated from the military missile technology, were going to be too costly if the space domain was to see anything more than military and occasional civilian automated vehicles.

Many of NASA's engineers, especially Dr. George Mueller and later Dr. von Braun, had outspokenly urged the development of a less costly launching system than the "expendables" (the single-use launchers). These men felt that the potential offered by the space domain would never be realized unless payloads and possibly men to work in space could be transported back and forth at something a lot closer to airline type operations. A reusable space craft, called the Shuttle, would be required, to become operational at the earliest possible date after the completion of the Apollo series.

Problems within NASA were compounded. The decision favoring the Shuttle development was not unanimous within NASA. Scientists whose major interests involved smaller probes and scientific satellites felt the double pinch of the overall decline of the NASA budget and the pressure to fund the Shuttle. They declared the Shuttle to be a non-scientific enterprise of great cost, needlessly diverting funds from their own endeavors. Joining them in these protests were groups from the academic community, likewise pinched on funding, who declared that the Shuttle (rather than NASA's declining budget) was wasteful and injurious to their own endeavors.

NASA's science programs were indeed diminished. Since the budget declined incrementally, some new starts were possible in one year but had to be reduced in scope, cancelled or postponed in subsequent years.

Nevertheless, during the turmoil of Paine's administration, planning for the Shuttle became more advanced. Paine was convinced that the Shuttle was an essential part of the Nation's future in space.

NASA's next administrator, James C. Fletcher, took office in April 1971, and immediately reviewed and approved the continuation of the Shuttle program. However, it was sharply downgraded in concept, to reduce cost. It was reduced in size and designed to carry an external and expendable fuel tank as well as two large solid rockets which were to be jetisoned but which would be designed for reuse.

The new, lower cost Shuttle was salable and Fletcher obtained President Nixon's approval for it on January 5, 1972. Within 5 years, by early 1977, the Shuttle has progressed to the stage of free flight testing.

When the Shuttle finally won approval, it seemed due to the heavy dedication to studies of the Earth and the convincing economics of its operations. NASA, to an increasing degree, was becoming a service agency, launching more satellites for others than for itself.

On June 21, 1977 Dr. Robert A. Frosch was sworn in as the fifth Administrator of the still declining space agency. The shrinking budget, about half that of 1966 in comparable dollars, reduced new starts still more. However, the picture was brightened by the continuing series of spectacular and successful free flights (drops from an

aircraft) of the first Shuttle, named the Enterprise. The second Shuttle, to be the first to enter space, remains on its current target for a launch date in September of 1979.

V. NASA Programs Shift Emphasis as Budget Declines

Most of NASA's scientific launches during the late 1960's and early 1970's required several years to complete. They required little funding during their year of launch, having been paid for in prior years. They could be called the products of an earlier momentum.

Planetary programs, such as Mariner, were heavily curtailed, although the Mariner program included some outstanding success in photographing Mars and revealed unsuspected sensor data from Venus as well as a close look at Mercury.

The Large Scale Telescope, to be an astronomy follow-on to the successful orbiting observatory series, was postponed and reduced in capability several times. The "Grand Tour" program, in which a long lived probe would be guided by nearly all the major planets, within photographic and sensing range, was reduced in scale a few times and finally cancelled to be replaced by less ambitious projects to the outer planets.

In space science, the major program was the Viking, a reduced version of the cancelled Voyager Mars program (not to be confused with Voyager 1 and 2 now enroute to Jupiter). Extensive mapping and highly successful soft landings on Mars were accomplished. Chemical and physical examinations of the surface yielded no clue that life had ever been present on the almost airless planet, nor did they disprove the presence of life. The mapping revealed a terrain far more rugged than any area of the Earth as well as large areas that appeared to be sculpted by huge quantities of flowing water, now apparently missing from the planet.

In contrast to the lack of interest in its programs of purely scientific interest, NASA found more enthusiasm in programs which had immediate economic payoff. The Earth-resources satellites found a ready clientele of governmental and commercial customers. The success of these "Landsat" vehicles (formerly called ERTS) in contrast to the decline of the space-oriented vehicles clearly demonstrated the shift of public and congressional interest in the space program.

VI. Retrospect

Setting political goals, or declaring a state of national emergency, has shown the United States capable of remarkably fast progress and high achievement. Since 1915, when the NACA was enacted, the NACA/NASA budgets (through 1978) have reached almost $70 billion. However, during the 46 years prior to Kennedy's stunning announcement in 1961 of the lunar landing goal, these budgets showed a total outlay of about $2 billion.

Throughout the period prior to and following World War I the United States had no political goals in aeronautics. Progress in aeronautics relative to the rest of the world, showed the United States to be in a technological back wash. This condition was sustained for more than 20 years.

Rapid strides to advance the art of aeronautics to upgrade the Nation's military air aim began only after participation in World War II seemed inescapable.

The pattern of effort to achieve a political goal, then relaxation, continued into the space age. The NASA budget began its long decline the year following a successful lunar orbit, prior to the actual lunar landings. As a political reality, the race to the Moon had been won at this point.

There has been a question raised by many people: Could our exploration of the space discovery become a national and even international field of intense mutual effort, in effect a peaceful "substitute for war?" It can be argued that the answer to this question would seem to be that the element of international competition, occasionally crystalized into the statement of a political goal, has always been and still seems to be a critical driving force.

CHAPTER FOUR

NASA FACILITIES AND TRACKING SYSTEMS

By Marcia S. Smith and Barbara A. Luxenberg
Analysts in Aerospace and Energy Technology

I. Introduction

As related in the previous chapter, NASA was established in 1958 using the National Advisory Committee for Aeronautics (NACA) as a nucleus. The NACA had several facilities which were transferred to NASA when the latter came into existence: Langley Field, Virginia (now Langley Research Center) and its associated facility, the Pilotless Aircraft Research Station at Wallops Island, Virginia (now Wallops Flight Center); Lewis Flight Propulsion Laboratory, Ohio (now Lewis Research Center); Ames Aeronautical Laboratories, California (now Ames Research Center); and the High Speed Flight Station (now Dryden Flight Research Center), California. Also transferred to NASA at the time of its creation were two Army programs: the space activities of the Army Ballistic Missile Agency at the Redstone Arsenal in Huntsville, Alabama (now Marshall Space Flight Center), and the Jet Propulsion Laboratory in Pasadena, California.

As the space program grew, more facilities were needed to support the goal established by President Kennedy in 1961 to land men on the Moon before the end of the decade. NASA launch facilities were added to the existing Air Force facilities at Cape Canaveral, Florida, (NASA's facilities are now named the Kennedy Space Center), and additional launch facilities were provided for NASA at the Vandenberg Air Force Base, California. The Manned Spacecraft Center was built outside of Houston, Texas to support manned spaceflight specifically (later renamed Johnson Space Center); the Goddard Space Flight Center in Greenbelt, Maryland was established to conduct automated spacecraft and sounding rocket programs, and manage the Spaceflight Tracking and Data Network (STDN) for tracking and acquiring data from orbiting satellites; the Michoud Assembly Facility in New Orleans, Louisiana was constructed to assemble launch vehicle components; the Mississippi Test Facility (later renamed the National Space Technology Laboratory) in Bay St. Louis, Mississippi was established to develop spacecraft components; the Slidell Computer Complex in Slidell, Louisiana, was transferred to NASA from the Federal Aviation Administration to fulfill computational requirements for NASA; and the Electronics Research Center was established in Cambridge, Mass. in 1964 (it was subsequently transferred to the Department of Transportation in 1970). NASA Headquarters, in Washington, D.C., is responsible for the overall management of the agency's operations, including determining programs and projects. Figure 4–1 shows the geographical location of each NASA facility.

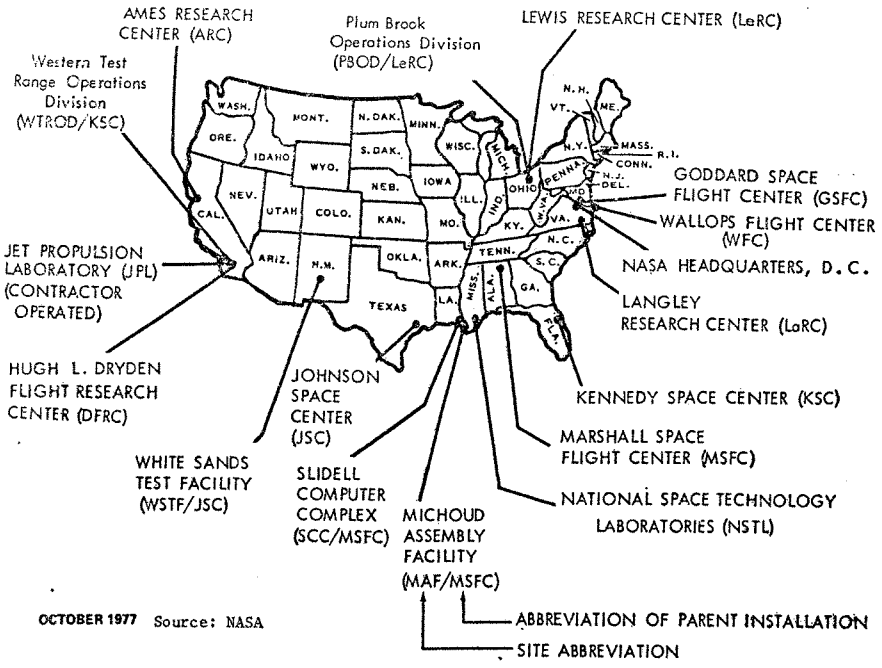

FIGURE 4–1

During the heyday of spaceflight, all these facilities were deemed necessary to fulfulling the Nation's space goals. As space flights declined, however, cutbacks in funding and personnel resulted, reducing capabilities at some of the centers. Questions have now been raised as to whether NASA needs so many centers to support its work for the decades ahead. Lewis Research Center and its Plum Brook Operations Division, for example, performs almost one-third of its work on energy matters, and the suggestion has been made that Lewis be transferred to the Department of Energy. Conversely, there is some concern that the funding and personnel cutbacks at some of the NASA centers may undercut NASA's capabilities in the future. Table 4–1 shows each center's current employment level (permanent full time positions) as of September 1978, and its peak employment.

TABLE 4-1

NASA EMPLOYMENT BY INSTALLATION*

INSTALLATION	CURRENT EMPLOYMENT	PEAK EMPLOYMENT (YEAR)
Ames Research Center	1,662	2,191 (1966)
Dryden Flight Research Center	489	618 (1964)
Goddard Space Flight Center	3,570	4,411 (1970)
Headquarters	1,512	2,447 (1967)
Johnson Space Center	3,523	4,862 (1967)
Kennedy Space Center	2,182	2,877 (1969)
Langley Research Center	3,065	4,285 (1965)
Lewis Research Center	2,899	4,819 (1966)
Marshall Space Flight Center	3,760	7,485 (1965)**
National Space Technology Labs	102	102 (1978)**
Wallops Flight Center	405	520 (1965)
TOTAL PERMANENT POSITIONS	23,169	

* Reflects permanent, full time positions. Current employment is as of September, 1978. Jet Propulsion Laboratory is not included because its personnel are employed by the California Institute of Technology, under contract to NASA. Figures for each installation include any affiliated facilities. For example, employment figures for Marshall include the Michoud Assembly Facility and Slidell Computer Complex, for which Marshall has management responsibility.

** Until 1974, the National Space Technology Labs were under the management of Marshall Space Flight Center. Therefore, the peak employment listed for Marshall in 1965 includes employment at NSTL (then the Mississippi Test Facility), while peak employment for NSTL is much more recent than for the other NASA installations.

The Jet Propulsion Laboratory, which is owned by the Government, but operated on a contractual basis by the California Institute of Technology, has been given increasing responsibility by NASA for planetary programs although its contractor-operated status makes it more expensive to perform work there than in other facilities owned and operated by the Government. Therefore NASA's increased reliance on JPL as its lead center for planetary missions is an issue of concern.

For tracking and data acquisition, NASA established a world-wide network of tracking stations for the STDN and Deep Space Network. In the early 1980's, however, most tracking and data functions will be handled by the four satellite tracking and data relay satellite system (TDRSS, see chapter 10), and many of these tracking stations will no longer be needed.

II. NASA Centers

A. DESCRIPTION OF EXISTING NASA INSTALLATIONS

There are nine major NASA centers in addition to headquarters: the Ames Research Center, Dryden Flight Research Center, Goddard Space Flight Center, Johnson Space Center, Langley Research Center, Lewis Research Center, Kennedy Space Center, Marshall Space Flight Center, and Wallops Flight Center. The Government-owned, contractor-operated Jet Propulsion Laboratory is also a major NASA facility, as is the National Space Testing Laboratory.

1. Ames Research Center

Located near San Francisco, California, Ames Research Center was founded in 1940 as the Ames Aeronautical Laboratories and named after Joseph S. Ames who had been chairman of the National Advisory Committee for Aeronautics (NACA) from 1927 to 1939. As a NACA facility, Ames was transfered to NASA when it was established in 1958. The center occupies 421 acres contiguous to the U.S. Naval Air Station at Moffett Field, California.

Programs at Ames involve research and development in aeronautics, space science, life science, and space technology, including short-haul aircraft technology, helicopter technology, flight simulation, computational fluid dynamics, planetary entry, airborne sciences and applications, and aeronautical and space life centers.

2. Dryden Flight Research Center

The Dryden Flight Research Center was originally established as the High Speed Flight Station under the NACA in 1947. When the station was transferred to NASA in 1958, it was designated Flight Research Center. In 1976, NASA renamed the facility after former NACA director (later NASA Deputy Administrator) Hugh L. Dryden.

The center occupies 521 acres of land at the north end of Edwards Air Force Base, California, about 65 air miles northeast of Los Angeles. Its primary duties are the conduct of aeronautical flight research in the areas of aerodynamics, structures, control systems, propulsion systems, disciplinary integration effects, safety, operations, and human-vehicle interactions. Dryden will provide landing and recovery capabilities for the space shuttle during the Orbital Flight Tests in 1979 and 1980, and is also involved in the development of remotely piloted vehicles.

3. Goddard Space Flight Center

Established in 1959, the Goddard Space Flight Center is named after American rocket pioneer Robert H. Goddard. Located 15 miles northwest of Washington, D.C., Goddard's main site occupies 554 acres, while three additional nearby sites occupy 640 acres. Part of Goddard's personnel are located at NASA's Goddard Institute for Space Studies in New York City.

Goddard manages an eclectic array of space activities, ranging from the development and operation of the world-wide Spacecraft Tracking and Data Network (STDN) for Earth orbital flights (including the space shuttle), developing scientific and applications experiments to be flown on satellites, and in some cases, constructing the satellites

themselves. Among the many satellite project managed by Goddard are Landsat, the International Sun Earth Explorers (ISEE), and GOES (Geostationary Operational Earth Satellite). Goddard is also responsible for NASA's sounding rocket program, including the Space Processing Applications Rockets (SPAR, see chapter eleven).

4. Johnson Space Center

To support implementation of President Kennedy's mandate to send men to the Moon by the end of the decade, NASA established the Manned Spacecraft Center about 20 miles southeast of Houston, Texas in 1961. In 1973, the center was renamed the Lyndon B. Johnson Space Center in honor of the former President who, as Senate Majority Leader, was instrumental in establishing NASA, and during his tenure as Vice-President under Kennedy, served as chairman of the National Aeronautics and Space Council.

Located on part of the center's 1,620 acres is the Mission Control Center, which is responsible for manned spaceflights once they lift off from the Kennedy Space Center. Beginning with Gemini 4 in June 1965, all manned space flights have been controlled in orbit from Johnson. The center is also responsible for the selection and training of astronaut crews, and the Lunar Receiving Laboratory was constructed there for housing astronauts returning from lunar landings during their quarantine period (a practice discontinued beginning with Apollo 15). The samples retrieved during the manned lunar landings are maintained at the center.

Johnson Space Center manages NASA's operations at the Army's White Sands Test Facility in Las Cruces, New Mexico. Beginning in 1962, NASA was allowed use of 54,080 acres of the Army center; the current agreement for use of the area expires on June 30, 1995. In 1964, an additional 1,409 acres were given to NASA for an indefinite period of time under a public land grant from the Department of the Interior. In 1978, 4,707 acres were set aside for NASA use under an inter-agency agreement between the Bureau of Land Management and the Army Corps of Engineers acting for NASA. This latter agreement will be reviewed every ten years by the parties concerned. NASA's White Sands Missile Facility is used for launching sounding rockets and testing launch vehicles.

5. Jet Propulsion Laboratory

The Jet Propulsion Laboratory occupies 176.8 acres of land in Pasadena, California, and was first established in 1944 to develop guidance and electronics for missiles for the U.S. Army. JPL produced the spacecraft and upper propulsion stages for the first U.S. satellite, Explorer 1. In 1958, JPL, along with other Army space-related facilities, was transferred to NASA.

JPL is a Government-owned facility, operated on a contractual basis by the California Institute of Technology. Its primary missions for NASA are operation of the Deep Space Network for tracking and data acquisition from deep space probes, and development and management of planetary programs. In addition to the tracking antennas at Goldstone, California, Canberra, Australia and Madrid, Spain, JPL has subsidiary facilities at Edwards Air Force Base, California for propellant formulation and testing, and Table Mountain, California for open air testing and astronomy.

6. Kennedy Space Center

The first space launches took place from the Air Force's Eastern Test Range near Cape Canaveral, Florida. When NASA was created, the decision was made that the new space program required additional launch facilities. After studying a number of sites, NASA decided to purchase land next to the Eastern Test Range for its own launch facilities.

The center was named Kennedy Space Center in honor of President Kennedy after his assassination in 1963, and Cape Canaveral itself was changed to Cape Kennedy. In 1972, the name of the cape was returned to Canaveral, but the NASA installation kept its designation as the John F. Kennedy Space Center.

NASA east-coast launches take place either from the center's own launch sites or those of the Air Force. Kennedy Space Center is responsible for manned space flights up until launch, at which time control is handed over to the Mission Control at Johnson Space Center. Kennedy also has a Western Test Range Operations Division at Vandenberg Air Force Base, California. NASA owns no real estate at the base, but performs launches there through an agreement with the Air Force.

7. Langley Research Center

NASA's Langley Research Center is by far the oldest of the NASA installations. Originally established as Langley Field in 1917, it was the Nation's only aeronautical research facility until Ames Research Center was established in 1940. The center is named after American aeronautical scientist Samuel P. Langley, and occupies 810 acres of land in Hampton, Va., contiguous to Langley Air Force Base.

Langley's primary missions include development of aeronautics and space technology, including long-haul aircraft technology, general aviation aircraft technology, acoustics and noise reduction, aerospace vehicle structure and materials, technology experiments in space (including development and management of the Long Duration Exposure Facility for use with the space shuttle), and advanced space vehicle configurations technology.

8. Lewis Research Center

Construction of Lewis Research Center was begun in 1941 by the NACA to perform research in aircraft engine technology, and was named in honor of former NACA Director of Aeronautical Research, George W. Lewis. As with the other NACA facilities, Lewis was transferred to NASA in 1958. The center today occupies two sites: the original site of the NACA facility, on 366 acres adjacent to the Cleveland-Hopkins (Ohio) International Airport; and the Plum Brook Station, located on 8,051 acres about 50 miles west of Cleveland, which was established in 1956 to investigate problems associated with nuclear propulsion.

Lewis' main responsibilities include space propulsion systems technology, space energy processes and systems technology, energy technology and application, and air breathing propulsion systems. Approximately 30 percent of Lewis' work is energy related.

9. Marshall Space Flight Center

When the Army's space activities were transferred to NASA in 1958, included was Wernher von Braun's team of space experts at the Redstone Arsenal in Huntsville, Alabama, then part of the Army Ballistic Missile Agency. The portion of Redstone Arsenal transferred to NASA became the Marshall Space Flight Center, named after General George C. Marshall, in 1960. The center occupies 1,840 acres in the midst of Redstone Arsenal under a nonrevocable use permit.

Marshall's primary mission has been development of launch vehicles, such as the Saturn family of boosters, and now includes development of the space shuttle main engines. Marshall also manages the Slidell Computer Complex in Slidell, Louisiana, and the Michoud Assembly Facility in New Orleans. The Mississippi Test Facility was under Marshall management until 1974 when it became a separate NASA facility and was renamed the National Space Technology Laboratory.

In addition to its launch vehicle development missions, Marshall has also been involved in development of scientific satellites, and manages the HEAO (High Energy Astronomical Observatory) program. Marshall is responsible for managing the Spacelab program, including developing a scientific base for space processing experiments.

10. National Space Technology Laboratory

Formerly the Mississippi Test Facility under the management of Marshall Space Flight Center, the National Space Technology Laboratory (NSTL) was made a separate NASA installation in 1974 and occupies 138,807 acres of land in southwest Mississippi, approximately 50 miles northwest of New Orleans. NSTL is NASA's prime static test facility for large liquid propellant rocket engines and propulsion systems, and was originally established to test stages of the Saturn V launch vehicle.

At the present time, NSTL is responsible for testing the space shuttle main engines and development testing of the ground test version of the shuttle orbiter and the main propulsion test article. NSTL also has responsibilities in the area of transferring applications of NASA-developed technology in remote-sensing, satellite communications, and environmental sciences to the user community.

11. Wallops Flight Center

In 1945, Langley Field, then part of NACA, established a facility off the Virginia coast on Wallops Island, named after John Wallop, a 17th century surveyor. Designated the Pilotless Aircraft Research Station, the facility was responsible for investigations into the problems associated with flight. With the creation of NASA in 1958, the facility was renamed Wallops Station and transferred to the new space agency. In 1974, its name was changed to Wallops Flight Center.

The center occupies three sites: the main base, about seven miles northwest of Wallops Island which has administrative offices, range control centers and main telemetry buildings; the island itself which is the launch site and is connected to the mainland by a causeway; and the Wallops mainland site which houses radar and optical tracking sites, and is one-half mile west of the island. The total acreage for all three sites is 6,166 acres.

Wallops was the site of many early launch vehicle tests, some in support of manned missions, including the Little Joe series of launches in support of Project Mercury. Its current missions include preparing, assembling, launching and tracking space vehicles and acquiring scientific information from them. An important aspect of Wallops' operations is developing and procuring sounding rockets and carrying out all phases of their operation, from mission and flight planning to landing and recovery. Wallops also maintains and operates a research airport in support of NASA's aeronautical programs.

B. INSTITUTIONAL ASSESSMENT

In 1975, NASA conducted an institutional assessment to determine if NASA's institutional configuration was optimal for the transition from the Apollo era to the Shuttle era, and if the additional manpower available from the completion of projects would fit new work prospects. The objectives of the study were to: clarify and consolidate the roles and missions of each Center; identify manpower becoming available from major work completion and compare it with potential needs; and determine where NASA might move work out-of-house to broaden technical interchange with universities and industry. It was recognized from the outset, however, that whatever roles and missions were assigned to each center would not be immutable. For example, if an employee at a center developed an innovative idea for a project not within the roles and missions of that center, the employee could still work at developing the idea without moving to a different center.

The assessment resulted in a reassigning of roles and missions at eight of the ten NASA centers (excluding NSTL and headquarters). All substantive changes were implemented during the next two years in terms of reassigning roles and missions, although there were some changes in the timing of the phasing out of programs. In summary, the following changes were recommended by the study: *Ames*—phase out of planetary spacecraft development, flight operations and associated planetary and space physics after Pioneer Venus, and phase out of long-haul aeronautical activities with increased focus on short haul systems (later Ames was also made the lead center for helicopter systems technology); *Goddard*—phase out of lunar planetary geoscience, reduced role in planetary science, and become lead center for development of Earth orbital free flyers; *Jet Propulsion Laboratory*—become lead center for developing all future automated planetary exploration spacecraft, increased role in planetary science, and designated as alternate for space science and applications Earth orbit free flyer developments; *Johnson*—phase out space physics and stratophysics research, increase role in lunar and planetary geoscience, and assignment of STS utilization planning and experiment/payload control for Spacelab, including data processing and distribution; *Kennedy*—change in assignments regarding integration responsibilities for the space shuttle and Spacelab; *Langley*—phase out planetary spacecraft development after Viking, elimination of Explorer development role, focus of aeronautical activities on long-haul aeronautical systems, with phase out of short-haul activities; *Lewis*—phase out of communications spacecraft development after CAS-C; and *Marshall*—phase out of space physics and astronomy science cap-

ability, phase out of STS utilization planning, elimination of biotechnology role, focus of free-flyer development role on specialized spacecraft, and change in responsibilities for shuttle and Spacelab integration.

NASA concluded during this assessment that, when implemented, the program decisions could result in a reduction of 500 civil service positions and 1,122 contractors, of which 105 would be JPL employees. In 1977, newly elected President Carter notified NASA that it would have to cut its personnel by 500 positions. Although this figure was not obtained from the NASA institutional management study, NASA's study facilitated the reduction of personnel to meet the President's directive. These personnel cuts took place in FY 78, except for 45 of the positions which were to be cut at Marshall Space Flight Center. These 45 positions will be cut during FY 79.

C. FACILITIES UTILIZATION PROGRAM

In 1976, the House Science and Technology Subcommittee on Space Science and Applications held a set of two hearings concerning NASA program planning and control. As a result of those hearings, the subcommittee recommended that NASA identify underused, deactivated or inoperable facilities at NASA installations, including not only buildings, but specialized equipment, such as wind tunnels.[1]

Pursuant to the subcommittee's recommendation, NASA issued a management instruction (NMI) in January 1977 to establish a uniform NASA facilities utilization program. The NMI requires an annual report from each NASA installation on major facilities (NASA identified 110 major facilities at its various installations), including a level-of-use assessment, an identification of the programs and projects supported by each facility, and a projection of use for the forthcoming year. The results of these annual reports will be used as an internal management tool for NASA planning.

III. Tracking Systems

NASA has developed a world-wide tracking system, including antennas, airplanes and, until recently, ships, to track and acquire data from its space missions. (The last of the five ships assigned to such missions, the U.S.S. Vanguard, was transferred to the U.S. Navy on October 1, 1978.)

The Spacecraft Tracking and Data Network (STDN) is used for tracking suborbital and Earth-orbital missions, manned and unmanned, and is managed by Goddard Space Flight Center. At the present time, antennas are located at several sites in the United States, Ascension Island, Australia, Bermuda, Chile, Ecuador, Spain and the United Kingdom. Goddard also houses data processing facilities and Mission Control Centers which provide the mission control functions for all automated Earth orbital spacecraft. Missions beyond Earth orbit are handled by the Deep Space Network (DSN) which involves three tracking stations (Goldstone, California, Spain, and Australia) which is managed by the Jet Propulsion Laboratory in Pasadena.

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[1] U.S. Congress. House. Committee on Science and Technology. Subcommittee on Space Science and Applications. NASA Program Planning and Control. Committee Print. 94th Cong., 2d sess. Washington, U.S. Govt. Print. Off., 1976.

Linking the control centers, antenna stations and data processing facilities together is a global communications system, called NASCOM (NASA Communications System) which uses telephone, microwave, undersea cable and satellite links, leased from domestic and foreign common carriers.

In the 1980's, NASA's suborbital and earth orbital tracking requirements will be handled primarily by the Tracking and Data Relay Satellite System (TDRSS) rather than ground stations. (The Deep Space Network will still be required for missions beyond earth orbit, while four STDN stations will remain open: those three co-located with the DSN in Australia, Goldstone, and Spain, as well as one in Alaska. The Merritt Island and Bermuda tracking stations will be retained for launch support only.)

As the time for the launch of the first TDRSS launch nears (originally scheduled for mid-1980) NASA is making plans to phase out some STDN stations. Each station usually has only one NASA employee, with the rest employed by contractors, such as the Bendix Corporation or the University of Chile, so station closings will not affect NASA employment levels substantially. If the equipment at the facility is no longer needed by NASA or any other government agency it will probably be donated to an educational institution in the country where the station is located.

TDRSS is planned for launch aboard the space shuttle. Recently NASA announced that the planned first launch of the shuttle would be slipped by three months, and there is a possibility that there may be additional delays. Of the STDN stations which will be closed, only one (Ecuador) is operated under an agreement with an expiration date (September 1979) and NASA is planning to renegotiate the agreement to cover whatever period of time is necessary before TRDSS is available. The other stations can be operated by NASA indefinitely.

CHAPTER FIVE

LAUNCH VEHICLES AND PROPULSION

By Charles S. Sheldon, II
Chief, Science Policy Research Division

I. Historical Origins

Principles of space flight and experimental rockets developed in several countries over many years, with the German A–4 (also called the V–2) in World War II the practical culmination of such work, from which much of modern rocketry has been derived. The A–4 military rocket with a range of 200 kilometers (120 miles) was to have been but the first in a series of German rockets leading to the creation of manned orbital stations.

The German technology and hardware, together with scientists or engineers and technicians came into the hands of the United States, the Soviet Union, the United Kingdom, and France. In the United States, the V–2 rockets brought to White Sands, New Mexico, and other places were used as sounding rockets, and their technology went into several different U.S. developments.

Historically there has been a rivalry between liquid fueled and solid fueled rockets. The pros and cons are complex and have changed over the years. Simplified, the liquid oxidant and fuel can be loaded at a time convenient to operations. To burn together, typically they may have to be pumped, or pushed by a neutral gas under pressure, or may be gravity fed. If either or both propellants is cryogenic (a cold, liquified gas), this substance has to be put into the rocket tank close to the launch time, and may require "topping" as some gas boils off before launch.

Solids typically produce less energy per kilogram of propellant weight, can be stored for extended periods, do not need pumping systems, but also provide an explosive hazard throughout their prelaunch life. Start-stop firing, and variable amounts of thrust from solids either are not available or may be more complicated to achieve than with liquids; such flexibility in rocket thrust is useful to adjusting flight behavior of the rocket.

The rivalry referred to continues to this day, but more often now, their respective uses are complementary.

II. Shared Technologies

It is not possible to trace all the interconnections among early U.S. rockets, but some of the most obvious can be identified. Also, the period after World War II until about 1960 was marked by a great proliferation of somewhat duplicative types of hardware as many agencies and companies were trying to find their places in what promised to be an important expanding field.

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The German team which had developed the V–2 was moved from White Sands to the Redstone Arsenal in Alabama where they developed the Redstone missile as the immediate successor to the V–2. Redstone was followed by a next larger generation, the Jupiter missile, and as space launch vehicles, these became part of the Juno family, which was intended to grow at least to the Juno V level (later Saturn I).

The rocket engine from the V–2 was adapted for use as a booster for the Navaho ram jet missile, and although the Navaho was cancelled before becoming operational, its engine continued to evolve to power the Jupiter, Thor, Atlas, and Titan missiles, both for first stages and for the upper stages of those systems with more than one stage. The ancestry is also apparent in the more advanced systems which later made up the Saturns.

The Jet Propulsion Laboratory in the early postwar days began development of the Corporal and WAC Corporal liquid fueled rocket systems. Briefly, the Corporal was a tactical missile used by the Army, but the Army later switched to the more convenient solid-fueled Pershing system. The Corporal was followed by the Sergeant system which in turn was the prototype for Castor, used both as the second stage of the Scout space launch vehicle, and as strap-on boosters for the Thor launch vehicle. The WAC Corporal was smaller, and served as the prototype for the large family of sounding rockets called Aerobee. The Aerobee provided the second stage for the Vanguard launch vehicle and then in turn became the second stage of the Thor Able and Thor Delta launch systems.

Larger than the Aerobee system was the Navy Viking sounding rocket. It grew into the first stage of the Vanguard launch vehicle, and was to have been used in the Atlas Vega launch vehicle as an upper stage.

When Vanguard was designed, a new solid-fueled stage called Altair was developed as its third stage, and later it became both the third stage of Thor Able and Thor Delta, and the fourth stage of Scout. Scaling up Altair created Antares, the third stage of Scout.

The advanced solid-fueled technology used in the Polaris naval missile was used for constructing the Aerojet Senior rocket, and this evolved into Algol, the first stage of Scout.

The B–58 Hustler Air Force bomber was to carry on air to surface bomb powered by a new rocket motor using storable liquid propellants. This engine was modified to power the Agena upper stage used with Thor, Atlas, and Titan.

III. Service Rivalries

Part of the proliferation of rockets and launch systems can be related to the intense competition among the Air Force, Army, and Navy for strong positions in the new weapons technologies; and later the National Aeronautics and Space Administration became a fourth claimant for a role and for funding.

The Air Force established the Ballistic Missile Division, working with technical help from the Ramo-Wooldridge Corp. (Later called Space Technology Laboratories.) Principal projects were the Atlas

ICBM (Convair) and Thor IRBM (Douglas), both using engines from Rocketdyne, derived from the Navaho. As a back-up with similar but somewhat more challenging technology, BMD also sponsored the Titan ICBM (Martin), with a similar engine from Aerojet. Later the Minuteman systems were added (Boeing) to exploit solid fuels.

The Army moved beyond the Redstone to the Jupiter IRBM, which used essentially the same Rocketdyne engine used for Thor and Atlas. A Jupiter tank surrounded by eight Redstone tanks was to be the basis for an 8-engined first stage of an advanced system called Juno V, later renamed Saturn I. Although Redstones and Jupiters were deployed with the Army combat forces, Redstone was superseded by Corporal and then Pershing, while the Jupiters were withdrawn from Italy and Turkey without replacements. The Army lost both the space team at Redstone and the Jet Propulsion Laboratory at Pasadena to NASA.

The Navy was originally a partner with the Army in plans to use Jupiter, but decided that it was too large and awkward to place in submarines, so opted for advanced technology in a small, powerful solid-fueled rocket which became Polaris. The Navy had been responsible for the marginal Vanguard space launch system, and Vanguard was phased out, with its several rocket stages going into other surviving Air Force and NASA vehicles as described.

After many bureaucratic maneuvers and considerable investment of money and talent, the ultimate shakeout was that space systems in the Department of Defense were placed under the management of ARPA (Advanced Research Projects Agency) until later the Air Force became executive agent for DoD. NASA was set up as the civilian counterpart with a prime role in guiding a national space program, except that the Department of Defense had considerable resources and independence to pursue what it considered important to its interests.

In many respects technology, vehicles, and facilities were shared between the Air Force and NASA, but there is also considerable evidence of continuing rivalry and even duplication.

IV. Space-Related Vehicles Which Reached Flight Status

A. LAUNCH VEHICLES

1. Vanguard

Vanguard was intended to be the first launch system to Earth orbit, in support of the International Geophysical Year (IGY). Early launches were disappointing failures beginning in 1957, and ultimately only three payloads out of about 12 reached orbit.

Redstone under the name *Jupiter C* had been available earlier than Vanguard but was prohibited from trying for orbital flight until after Vanguard had experienced its first failures. Then Jupiter C was prepared on a time urgent basis and carried Explorer 1, the first U.S. satellite to orbit early in 1958. When the upper stages of Jupiter C—clusters of small solid rockets—were mounted on the larger Jupiter, the orbital vehicle was called *Juno II*, and was used briefly as a launch vehicle, but soon was phased out. *Redstone* itself made a brief comeback as the suborbital test vehicle for Project Mercury.

2. Thor

Thor, the IRBM, provided the Air Force with a more powerful launch capability than the Vanguard of the Navy or the Redstone/Jupiter types of the Army for launching to orbit. But Thor required upper stages, and these came first from Vanguard, as described, to create the *Thor Able* system. Thor Able was used first to test ICBM warhead reentry, and then was used to make early launch attempts to reach the Moon (unsuccessful). Thor Able was also used for a few Earth satellite flights, before it evolved in two new directions. With a restart capability, it became the *Thor Able Star*, used primarily for orbiting Navy payloads before being phased out. Another variant intended as a interim NASA vehicle was called *Thor Delta.* This was so successful that it has continued in use down to the present time, but with many product improvements to increase capacity and versatility.

The Thor first stage now operates with attached booster rockets, and the Thor tanks have been lengthened. The Delta upper stages have been improved and for some missions consist of one stage and in other cases two stages, aside from apogee motors carried by some payloads which need circularized orbits at high altitude.

The early Thor Able launch vehicles were quickly exceeded in lift capacity when the Air Force brought into use the *Thor Agena* combination, intended originally for classified military programs, and later used more widely.

3. Atlas

Atlas, as an ICBM, was still more powerful than the Thor. Its first space use was for project Score, when the whole sustainer stage was placed in orbit. (A sustainer stage refers to the core vehicle and engine which continue to function from launch to space, while the booster engines, also ignited at launch, separate and fall back earlier.) *Atlas Able* coupled the Atlas with the Vanguard stages as in the manner of Thor Able, and created a more powerful launch vehicle to place payloads in orbit around the Moon. Not one of the four built was successful in this regard. However, Atlas with the Agena stage, *Atlas Agena* found a useful continuing place in the launch vehicle stable. Atlas also has been used to carry a high energy stage to create the *Atlas Centaur* system.

Both Thor and Atlas also have some limited use with a variety of minor upper stages equipping them to carry technology experiments to orbit or military weather satellites.

4. Scout

Scout is the only all-solid launch system, and has the smallest capacity of the several continuing vehicle systems. Its derivation from other systems has already been traced. Over the years, each of the four stages has been replaced one or more times, improving the lift capacity markedly.

5. Titan

Titan was the ICBM in parallel development to Atlas, with the principal original difference being that the upper stage was ignited at altitude rather than on the ground in parallel staging as done with Atlas. But Titan I was soon replaced by a more powerful and con-

venient system which used storable propellants instead of cryogenics, and this was *Titan II*. Just as Atlas had been used for the orbital flights of Mercury, Titan II was used for the flights of Gemini. Titan II then evolved into *Titan III*. *Titan IIIA* was externally not too different from Titan II in appearance except for its addition of another stage. *Titan IIIB* was a further evolution which normally carried the Agena stage. *Titan IIIC* was a bigger advance, because it included two large solid-fuel strap-on booster rockets. Titan IIIC also normally carried a Transtage, a multiple restart third stage. *Titan IIID* was similar in appearance to the Titan IIIC, but was supposed to be more economical in terms of the lesser stringency of some aspects of performance, and lacks the Transtage. *Titan IIIE* is like a Titan IIIC but with a Centaur stage in place of the Transtage.

6. Saturn I

Saturn I was the original test version of the NASA vehicle intended to carry men to the Moon. The first stage used eight engines of the H–1 class, essentially the same as used in Thor, Atlas, and Jupiter. The second stage, when powered, carried eight engines of the type used in Centaur. *Saturn IB* was similar to the Saturn I but substituted a new upper stage which carried a more powerful single J–2 engine in place of the 8 RL–10 engines.

7. Saturn V.

Saturn V was the largest operational vehicle in the world. It was powered in the first stage by five F-1 engines of 675,000 kilograms (1.5 million pounds) of thrust. The second stage used five J–2 engines of 90,000 kilograms (200,000 pounds) thrust each. The third stage used a single J–2 engine, the same stage as used on the Saturn 1B. A few remain in storage.

B. UPPER STAGES

1. Able and Able Star

For the most part, upper stages have been identified already. Able and Able Star were the interim stages used on Thor or Atlas. As explained, they were derived from Vanguard.

2. Delta and Improved Delta

Delta and Improved Delta are derivatives of Able and are NASA stages used on Thor.

3. Agena A, B and D

Agena A, B and D represent the evolution of this Air Force stage also used by NASA. The early A version was interim until B was substituted with a restart capability. The D version was a standardized, improved type which continues in use. It is used on Thor, Atlas, and Titan.

4. Centaur

Centaur was the first high energy upper stage, and continues in use on the Atlas and Titan.

5. Lesser stages

Lesser stages finding limited use have been the Altair and FW–4 on Thor and Scout, the Burner II on Thor and Atlas, and the F–364–4 on Atlas.

6. Planetary stages

A variety of planetary stages with storable propellants have made it possible to do flight path adjustments and to go into orbit around other planets.

C. BOOSTER STAGES

The principal boosters have been the three, six, or nine strap-ons used with Thor, with the option of using either of two sizes of such strap-ons. For Titan III, the strap-ons are two very large segmented solids, either of five or five and one-half segments.

D. SOUNDING ROCKETS

Despite the emergence of orbital capabilities, sounding rockets continue to be used widely because they come in many sizes down to quite economical; they can measure phenomena at particular places and times; they can measure data from the surface through the atmosphere to the high point of the flight, a capability not directly available to satellites.

An enormous variety of sounding rockets have been developed, as to size, weight lifting capacities, achievable altitude, degree of stabilization, liquid or solid fuel systems, sponsoring agencies, and manufacturers. Sounding rockets also have been used widely in international programs, and the launches have occurred in many parts of the world including use of ships at sea.

E. MISCELLANEOUS

Closely akin to sounding rockets for scientific purposes are other rockets used for suborbital tests in engineering development. Typical were the *Little Joe* flights used to test the recovery of Mercury capsules, *Big Joe* for the reentry of Mercury from space, *Shot Put* for the deployment test of Echo communications balloons, and even *Titan II* and *Saturn IB* for tests of Gemini and Apollo respectively before manned flights began in those programs.

F. OVERALL

Because of risks of interagency rivalry and duplication, once NASA and the Air Force became the surviving launching agencies, they agreed upon the establishment of a single National Launch Vehicle Program, in which each was to share data and make available vehicles for launching payloads of the other agency. In retrospect this seems to have worked reasonably well, but the sharing seems on the surface to have been less than perfect. For example, it seems curious that virtually every launch vehicle and upper stage has gone through a continuing process of improvement over the years, but Agena, so closely associated with special programs of the Air Force, would outwardly

seem to have been static for about 15 years. despite regular use, rasing the question as to whether its evolving has been kept classified. The Titan IIID is always pictured in public drawings as having a blank above the second stage except for the shroud, even though its payloads make maneuvers in actual flight after the second stage is discarded, suggesting another unannounced stage exits. For a long period the characteristics of the Burner II upper stage were never described in public reports. Some other upper stages on Thor and Atlas used by the Air Force are not identified in public reports.

Anyone keeping track of U.S. vehicle capabilities and performances faces difficult problems because of the constant evolving of these systems, which particularly in the case of Scout and Thor Delta, have been through so many changes. If one refers to the official tables on vehicle characteristics published in the annual report of the President to the Congress, these from one year to another are inconsistent as to what vehicles make up the National Launch Vehicle Program, what particular versions of these models are in current use, and what their performance characteristics are. Although it may be a clerical problem only, the end result is to confuse any analyst relying upon these data.

V. Vehicles and Propulsion Which Were or Are Committed to Development But Not Yet Flown

A. VEGA

While NASA was awaiting the completion of the Atlas Centaur system, it spent money on Atlas Vega, which used a modified Vanguard first stage as the second stage of Vega, It was only after a considerable effort had been invested to develop Vega that it was dropped completely because the Air Force made the restartable Agena stage available for NASA purposes.

B. ROVER

For many years, a large-scale effort was made to develop a solid core reactor nuclear rocket under the project name of Rover. The effort proved difficult, but major obstacles were overcome, and NASA saw future nuclear systems as important to increasing the effectiveness of transportation systems for reaching the Moon and planets. Rover used Kiwi nonflying reactors, Nerva and Phoebus engines designed to lead to flight articles, and was working on Rift (reactor in flight). The project was canceled after this very large investment for reasons of budgetary crunch coupled with the policy decision that there was no explicit mission which had been accepted as a national goal.

C. SERT

A variety of electric propulsion systems have been worked on over the years. and two of these reached experimental flight status under the name Sert. But priorities and funding were not very high in comparison with chemical propulsion projects and only now is NASA moving more explicitly toward designing electric propulsion systems for use in the late 1980s.

D. LARGE SOLID FUEL ROCKETS

Before the Saturn V was settled upon as the chosen means for sending men to the Moon, an intensive campaign was waged in the engineering community and before Congress to substitute large solid rockets at least for the S–1C liquid fuel stage. These efforts were not successful.

The Air Force did sponsor tests of 4 meter (156 inch) diameter segmented solid booster rockets to increase the capacity of Titan III in place of the existing 3 meter (120 inch) segmented rockets. This larger size was close to the limits of what could be trucked or carried by rail from manufacturer to launch site. In the end, the mission need was not viewed as urgent and work stopped after successful tests.

The Air Force also at one point commissioned 3 meter (120 inch) booster rockets made up of 7 segments each to create the Titan IIIM rocket to carry the DynaSoar and then the MOL (Manned Orbiting Laboratory) to orbit. With the demise of each of these programs in turn, the Titan IIIM and its seven-segmented rockets was dropped from the program.

The Air Force also was responsible for letting contracts for experimental solid rockets with a diameter of 6.6 meters (260 inches) built as single cases and loaded with solid propellant at the test site. Later, the responsibility was passed from the Air Force to NASA. The results were generally encouraging (with some instability and breakup in one test), after both half-length and full-length rockets were tested. Then for lack of funds and lack of agreed-upon mission, the work came to an end.

E. THE ENTERPRISE CLASS STS (REUSABLE SHUTTLE)

This project is the current principal launch means planned for the National Launch Vehicle Program. Funded by NASA, it will serve both NASA and the Air Force. To avoid annual budget peaking problems, the design has retreated from two completely recoverable stages, both manned, to a recoverable manned orbital vehicle lifted by two solid fuel rocket boosters which, it is expected, can be recovered at sea and refurbished, plus a large external propellant tank which will be expended with each flights.

Another part of this study details further aspects of the Shuttle.

F. THE SSUS–D AND A

While the hope is to place in service eventually one or more types of versatile, reusable space tugs, manned or unmanned, the immediate need is for extra stages carried within the Shuttle to reach those many types of orbits beyond a few hundred kilometers above the surface of the Earth which set the upper limit of Shuttle flight. The SSUS (Spinning Solid Upper Stage) is viewed as the first step, using solid fuel rockets which can be spun for stabilization, and providing them in two sizes, the smaller useful either with the Shuttle or the expendable Thor Delta (SSUS–D) the larger useful with the Shuttle or with the Atlas Centaur (SSUS–A). These will be supplied by McDonnell Douglas as a commercial venture.

G. THE IUS

Orginally referred to as the Interim Upper Stage, this is now called the Inertial Upper Stage, to be carried by the Shuttle. Boeing is to develop this, based upon its experience with the smaller Burner II. It will use different combinations of two sizes of solid fuel rockets, depending upon the mission, and will exceed the capacity of the SSUSs.

VI. Examples of Advanced Technology and Other Proposals

Only selected examples of other space technology projects can be described in this context because of their number, but they give a good cross section of both engineering vision and entrepreneurial effort.

A. NOVA

Before the decision was made to use LOR (lunar orbit rendezvous) for the Apollo program, NASA kept the option of direct flight to the Moon which would have required a much larger launch vehicle than the Saturn V. Design studies were well advanced for several different configurations using the F–1 engine, but construction was not undertaken.

B. SOLID ROCKETS

Reference has already been made to the 4 meter (156 inch) and 6.6 meter (260 inch) solid rockets. Manufacturers over the years had many additional solid rocket proposals to offer to NASA or the Air Force, which were not accepted.

C. HIGHER PERFORMANCE CHEMICAL SYSTEMS

1. Air augmentation

Many technologies have been tested at least at a modest scale by NASA in improving rocket performance. One approach was to funnel in extra air (Air Augmentation) for the first stage of multistage rockets.

2. Flox

Another was to saturate the liquid oxygen with fluorine (Flox) to produce a more energetic propellant.

3. Hydrogen-fluorine

Considerable effort went into adapting some existing engines to burn hydrogen and fluorine, to give a more powerful combination than the high energy hydrogen-oxygen combination now used for high performance.

4. Chamber pressures

Another approach has been to continue use of existing propellants but to raise chamber pressures for the burning of propellants. This has been an important factor in Soviet high performance rockets, and also is the key to an engine usable for main propulsion in the U.S. Shuttle.

5. Plug nozzle and aerospike

Research has been done on a variety of Plug Nozzle and Aerospike designs to increase the efficiency and performance of rockets. One reason for this interest is that the exhaust nozzle of a rocket in normal bell shape and fixed position is not equally efficient at all altitudes while the rocket passes through the atmosphere. Moving into position nozzle extensions mechanically presents some difficulties of design. Plug Nozzles and Acrospikes also afford an opportunity for building a more compact stage, and for combining many smaller combustion chambers which are easier to engineer than reliable large combustion chambers.

D. ADVANCED NUCLEAR SYSTEMS

1. Orion

For a period there was some interest in a nuclear system called Orion which would have fired a series of small nuclear charges behind the space ship, with the force of the explosion hitting against a large plate on springs to push the ship forward. This was tested commercially on a small scale with chemical explosions, but was not developed to flight status.

2. Gaseous core nuclear reactor

Some nuclear advocates saw many limitations to the Rover solid core nuclear rocket system (described earlier) because the high specific impulse of the heated hydrogen propellant would be offset by the weight of the reactor. Instead, these engineers saw a brighter future for the gaseous core nuclear reactor. The engineering problem with the gaseous core was to find some way to contain the much hotter nuclear portion of the system, either through a "light bulb" which would be transparent to most of the nuclear energy so that this energy could be captured by the external flow of hydrogen propellant seeded with an opaque material, or a centripetal system which would whirl the reacting nuclear material in the center of the reactor while the propellant swept by it inside the reactor to be heated and expelled from the rocket. Either approach showed some promise of possible success but extremely difficult problems of practical accomplishment within the time frame and funding available. Were such a system to become practical, parametric studies suggested far lower costs for space transportation and flights possible throughout the region of the inner planets in a matter of a few days rather than many months.

E. ELECTRIC PROPULSION SYSTEMS

Electric propulsion relies upon very high specific impulses to cut down on the amount of propellant to be used and to offset the weight of the total power conversion system. The thrust is usually very limited, but the gradual acceleration built up over weeks or months can result in very high speeds.

Many different design approaches have been used in experiments including *ion*, *plasma*, and *arc* or *resisto-jet*. Each has its own tradeoffs of reliability, thrust-to- weight ratios and specific impulse. The electricity to power the system may come from a nuclear reactor, a radioisotope thermal generator, a solar concentrator, or solar cell panels. Of all of these, at the moment solar cell panels seem to be preferred for future U.S. deep space missions.

F. SOLAR SAIL

NASA has also studied the deployment of large, thin surfaces, perhaps spread over an area of a kilometer or two in each direction, so that solar wind pressure could provide a means for deep space flight. While attractive, this has not been included in the current program, as solar-electrical has seemed more readily achievable.

G. "BIG DUMB BOOSTERS"

Despite the reliability and moderate cost per pound of the Saturn V in actual practice, many engineers have not seen such systems as the path of large scale growth of space travel because of the total cost per flight and the special care required at every stage of construction and operation. Many proposals in the past were made for a variety of systems which would seek cheaper construction methods and such simplicity of design that reliability in performance might be traded off against the lesser efficiency of these proposed non-refined systems. Some suggested that very large rockets could be built in ship yards of normal steel plate, and the loaded rocket floated out to sea for launch without the use of an expensive pad and reserved real estate. The design approach was not accepted, and the very advanced but reusable Shuttle was adopted instead.

H. HEAVY LIFT LAUNCH VEHICLES

Even with the Space Shuttle, there may be a number of missions which will require the launch of larger payloads than can be carried by the Shuttle. No commitment has been made for the construction of a Heavy Lift Launch Vehicle, but many design concepts are under study. There are trade-offs of cost and complexity in relying on orbital assembly of many payloads carried from Earth by the Shuttle versus the use of new solid rocket large launch vehicles, or new systems using many of the components from the Shuttle to create such logistics support systems.

I. SPACE TUGS

Versatile and reusable systems of vehicles, whether manned or unmanned, have long been planned to move payloads beyond the low altitude attainable by the Shuttle to reach other higher altitudes, to retrieve old payloads, to carry unmanned or manned equipment to geosynchronous altitudes, to land ships on the Moon or to launch deep space missions. Design studies are underway, but construction is not funded.

J. ADVANCED SHUTTLES

Of necessity the Enterprise class of shuttle is a compromise for reasons of funding, time, and technology now available. These ships will wear out, and difficult questions lie ahead as to whether to maintain a production line at a slow pace, with minimal new R&D, or whether to begin now to design and start the work toward advanced systems. Advanced systems might use more copies of the present orbital stages, but replace the solid fuel rocket boosters and external expendable propellant tank with a *fully reusable manned first stage.*

Another approach of interest is to develop technology to the place that a *fully reusable single stage to orbit* might be achieved. This would have the conceptual simplicity of an aeroplane able to reach space and return without the necessity of supplementary parts to throw away or recover separately. What is certain is that the present design of Shuttle for all its virtues still has much higher operating costs than parametric engineering studies show might be achievable if we improve our knowledge of materials and propulsion.

K. ADVANCED PLANETARY STAGES

Perhaps most reliable are simple solid propellant stages which can be used for braking on arrival at another planet. Also proven are liquid storable propellant systems using hypergolic fuels that are certain to ignite on command and designed to be turned on and off many times. These have functioned on lunar and planetary flights. But higher energy, space-storable systems can greatly increase the efficiency and hence the performance of future missions. Some such systems must respond to commands years after the original launch from Earth. Such candidate systems are under study for use in the late 1980's and after.

L. VERY ADVANCED PROPULSION

The *gaseous core nuclear systems*, because of their engineering challenge, probably belong in this category. The theorists and laboratories are also doing exploratory studies on other possible systems for employment at some indeterminant time. Among the ideas being thought about are various applications of *metallic hydrogen* fuel, if it could be created in stable form, *magnetohydrodynamics*, *lasers*, *fusion power*, and *photon rockets* which would convert mass into pure energy. Some of these systems might be used in combination. The more remote are seen as leading the way to unmanned and even manned expeditions beyond the solar system into other parts of the galaxy, at least to other "nearby" stars, if it can be established there is a good likelihood of their having planets.

All of these approaches are far from winning support for intensive development, but studies requiring only a low level of funding might open the door to advanced technology. Even the most advanced of today's space systems represent largely the application of techniques which were fairly well known at the time NASA was created in 1958. If the past is any lesson, there will be new scientific discoveries which ultimately can be exploited in practical terms. But breakthroughs which are truly new do not come by a predictable timetable or by command.

VII. IMPLICATIONS

The last quarter century of space development has been crowded with striking new developments, some disappointments, and much controversy. While by now much of this record is largely of historical interest, these experiences give insights into current issues, some of which are extremely difficult to resolve to the satisfaction of all participants, as they must be made in the framework of limited budgets and other demands on our resources.

The issues section of this study identifies some of the current launch vehicle, space vehicle, and propulsion issues, such as those that revolve around backup plans to the Shuttle, heavy lift vehicles, the next generations of Shuttle, the need for added stages beyond the Shuttle, future propulsion means, environmental factors, and the issues of launch vehicles being developed by other nations.

CHAPTER SIX

MANNED SPACE FLIGHT THROUGH 1975

By Marcia S. Smith
Analyst in Aerospace and Energy Technology

Of the many facets of the space program, manned space flight has traditionally received the most media attention, and consequently has high public visibility. This has both helped and hindered the program, since its funding and level of effort is inseparably tied to public opinion. Only two countries, the United States and the Soviet Union, have manned space programs and they have been constant rivals for headline producing events. During the early years of the space program, this competition resulted in public and congressional support for manned space flight, and funding levels sufficient for a program to land men on the Moon were approved. As the years passed, other considerations—the Vietnam War, rising inflation, increasing social problems—overshadowed space program achievements, and public acceptance of spending large sums of money on the space program diminished.

I. The Kennedy Mandate

In January 1961, the United States inaugurated a new President, John F. Kennedy. Aware of America's low image in science and technology, due in part to the lead the Russians had achieved in space flight, including launch of the world's first satellite, Sputnik I, in 1957, Kennedy chose the space program as a vehicle for restoring confidence in America's technological leadership. On April 12, 1961, the Russians accomplished another space first by putting the first human being, Yuriy Gagarin, into space. Gagarin's flight was followed only five days later by the Bay of Pigs incident, further eroding the United States' international position.

On May 25, 1961, three weeks after Alan Shepard became America's first man in space (although his flight was suborbital), President Kennedy spoke before a special joint session of Congress on May 25, 1961 and called for the United States to commit itself to the goal of landing a man on the Moon by the end of the decade. Convinced that the Russians had a similar goal in mind, and not wanting to be outperformed again, Congress and the American public accepted the challenge. The "Moon race" was on.

II. The Mercury and Gemini Programs

Spurred by the enthusiasm of the President, Congress and public, the National Aeronautics and Space Administration (NASA), which

had been established in 1958 to conduct the nation's civilian space program, formulated extensive plans for manned (as well as unmanned) space flight.

The Mercury program, already underway at the time, was designed to provide basic information about man's reaction to spaceflight. Six Mercury missions were flown, including the first American in space (Shepard), and the first American to orbit (John Glenn on February 6, 1962), which occurred almost a year after Gagarin's orbital flight.

The Gemini program followed Mercury, and was designed to develop skills in rendezvous and docking procedures between two spaceships, to test the effects of longer duration space flight on man, and to acquire experience with extravehicular activity (EVA). During the Gemini program the United States caught up with and overtook the Russians in manned space flight accomplishments. Although the first U.S. extravehicular activity (EVA) by Ed White in June 1965 came after the first Russian EVA in March, the Americans continued to perform EVA during successive Gemini missions while the Russians did not do so again until 1969. The Americans also developed rendezvous and docking expertise and set new space duration records.

III. The Apollo Program

By the end of the Gemini program in 1966, the United States was making steady progress towards achieving President Kennedy's goal. The Apollo program, designed to land men on the Moon, was next.

In 1967, however, tragedy struck both the American and Russian space programs. On January 27, the crew of the first Apollo mission was killed in a pre-launch test of their Apollo 204 spacecraft. Virgil "Gus" Grissom, Roger Chaffee, and Edward White were asphyxiated by toxic fumes when fire, ignited by a spark from an electrical short circuit, flashed through the 100% oxygen atmosphere of their cabin. Three months later, on April 24, the pilot of the first Soyuz spacecraft, Vladimir Komarov, was killed upon impact with the Earth when the parachute lines of his spacecraft tangled during descent from orbit. Both programs were set back for more than a year.

When the two programs resumed in 1968, there could be little doubt as to which country was further advanced in the race to the Moon. The first American flight was Apollo 7 on October 11, a test of all the components of the lunar Apollo spacecraft. Three months later, the Apollo 8 crew, Frank Borman, Jim Lovell and Bill Anders, spent Christmas in orbit around the Moon. The first Russian flight was Soyuz 3, launched on October 26. With this flight, the Russians finally accomplished manned rendezvous, a feat accomplished by their American counterparts years earlier. Public statements by Soviet space officials were no longer as optimistic about beating the Americans to the Moon, and some began to claim that the Russians either had never intended a manned lunar landing as a goal, or that being "first" was unimportant. In the United States, questions arose as to whether there had

ever been a "Moon race," or if it had simply been a ruse to get increased funding for space projects.[1]

Rising defense expenditures for the Vietnam War, coupled with social unrest and inflation, brought the space program under increasing scrutiny in its annual budget requests.

On July 20, 1969, Neil Armstrong and Edwin "Buzz" Aldrin set foot on the surface of the Moon, while command module pilot Michael Collins orbited above them. Although it may have been "One small step for man, one giant leap for mankind," it was also the beginning of the scaling down of the manned space program. NASA had planned to have an "Apollo Applications Program" running concurrently with the lunar Apollo program using space stations to develop expertise in exploiting near-Earth space. By the beginning of fiscal year 1971, however, just one year after the first lunar landing, NASA had to cancel the last three lunar landings (Apollo 18, 19 and 20), and substantially revise its plans for Apollo Applications because of reduced funding.

In total, six Apollo crews landed on the Moon and returned 2,196 samples weighing 841.6 pounds (381.7 kilograms) of lunar material for study: Apollo 11 (Armstrong and Aldrin), Apollo 12 (Conrad and Bean), Apollo 14 (Shepard and Mitchell), Apollo 15 (Scott and Irwin), Apollo 16 (Young and Duke) and Apollo 17 (Cernan and Schmitt). An oxygen tank exploded on Apollo 13 while it was enroute to the Moon, aborting its lunar landing mission. The crew survived by using the lunar module, with its independent life support systems, as a lifeboat for the three and a half days it took the spaceship to swing around the Moon and return home again. The crew was safely recovered, but the Apollo 13 incident was the closest the United States has come to losing astronauts in space.

Approximately $41 million has been spent analyzing the lunar samples. In its FY79 budget request, NASA asked for an additional $5.7 million to continue the investigations. Congress raised the issue of whether NASA is the appropriate agency to conduct lunar sample analysis since it is part of the more general field of geology which is under the jurisdiction of the National Science Foundation. Senator Proxmire, chairman of the subcommittee with jurisdiction over NASA appropriations, stated that lunar sample analysis should have to compete for funding with other geology programs. Congress finally resolved to appropriate only $1 million of the $5.7 million requested for FY79. Congress had previously denied funding for an addition to the Lunar Curatorial Facility at NASA's Johnson Space Center in both FY76 and FY77 budget requests. NASA had claimed that the

[1] During the early and mid-1960's, Russian space officials were often quoted in the press predicting Russian manned lunar landings, lending credence to the theory that they were "racing" with the United States. For example, on July 11, 1966, cosmonaut Vladimir Komarov, who was later to lose his life in the Soyuz 1 accident, stated: "There is no need to make haste about a Moon trip by human beings—and the important thing is how to carry out everything in safety. But I can state positively that the Soviet Union will not be beaten by the United States in a race for a human being to go to the Moon." (Asahi Shimbum, Tokyo, July 11, 1966). As the success of Apollo 8 loomed nearer, though, public statements changed. Cosmonaut Titov was quoted as saying on December 20, 1968 that "It is not very important to mankind who will reach the Moon first and when he will reach it. . . . We will undertake a flight to the Moon, but we will undertake it for scientific purposes." (Sofia BTA, December 20, 1968, 0815 GMT). A chronology of statements made by Soviet officals concerning their space program can be found in two publications of the Committee on Aeronautical and Space Sciences of the U.S. Senate: Soviet Space Programs 1966–1970 (pp. 359–384), published in 1971; and Soviet Space Programs 1971–1975 (pp. 525–552), published in 1976.

addition was necessary to ensure that the samples were adequately protected against both natural and man-made hazards.

Advocates of NASA's lunar sample analysis program have expressed concern that the samples, obtained at great cost to the United States, may now be neglected and not treated as the national treasure they are.

IV. Skylab

By the end of the lunar Apollo program in 1972, the space program's pace had slackened considerably. Plans for the Apollo Applications Program, renamed Skylab in 1970, had shrunk from plans for at least two space stations to which a total of seven crews would be sent, to a single space station occupied by three successive crews.

On May 14, 1973, the Skylab orbital workshop was launched, but during launch, the meteoroid shield surrounding the space station was ripped off, taking with it one of the solar panels which provide electrical power to the station. The other solar panel only partially deployed once in orbit. The first Skylab crew, launched on May 25, erected an "umbrella" shield over the station to prevent overheating from the intense radiation of the Sun, and was able to completely deploy the remaining solar panel, which was sufficient to power the station for the three manned missions.

The first Skylab crew remained in orbit for 28 days; the second crew, launched on July 28, remained for 59 days; and the third crew, launched on November 16, set a new space duration record by remaining in space for 84 days.[2] The three crews collected a wealth of information about the Earth, Sun and other astronomical objects, including Comet Kohoutek, and performed a wide variety of space processing and biomedical experiments.

The last Skylab crew departed from the space station in February 1974. At that time, Skylab's orbit was expected to decay sometime in the early 1980's. Increased solar activity, though, resulting in increased friction between the atmosphere and the space station, has caused it to decay more rapidly than previously predicted. NASA has placed Skylab in a minimum drag attitude to see if it will remain in orbit until the space shuttle is available to attempt to reboost Skylab to a higher orbit and extend its lifetime.

Some concern has been expressed that portions of the 85-ton (77,111 kilogram) vehicle might survive reentry through the Earth's atmosphere and impact a populated region of Earth. This concern was triggered by the unplanned reentry of a Russian satellite, Kosmos 954, in Canada in the spring of 1978. The satellite carried a nuclear reactor on board for power supply and was supposed to go into a high Earth-orbit such that the orbit would not decay until there was no danger from any residual radioactivity. A malfunction caused the satellite to reenter over a remote region of northern Canada, and although no one was seriously injured, either from the satellite itself or from any radioactive debris, international concern over satellite reentry has developed, resulting in increased media attention for the Skylab situation. Since the main factor affecting Skylab's reentry date is solar activity, and the level of that activity cannot be predicted precisely, NASA cannot definitely determine when reentry will occur. Eighty

[2] That record was not broken until March 1978 when a two-man Russian crew stayed in space aboard their Salyut 6 space station for 96 days.

percent of Skylab's orbit is over water, although the other 20% (between 50° north and 50° south latitude) is where most of Earth's population centers are located.

V. The Apollo-Soyuz Test Project

The last U.S. manned space mission was the Apollo-Soyuz Test Project (ASTP), which took place in 1975. Not only did ASTP mark the end of an era in space exploration, in that it was the last time the United States would use an expendable launch vehicle to send astronauts into space (the space shuttle is a reusable system), but also marked the first time that spaceships from two nations docked together in orbit.

The purpose of ASTP was to demonstrate that the major space powers, the Soviet Union and United States, could cooperate in a major space effort. On July 15, 1975, a Russian Soyuz spacecraft carrying two cosmonauts was launched into orbit. Seven hours later, an American Apollo spacecraft, carrying three astronauts, was launched. On the 17th, the two spaceships docked together and remained linked for two days while the crews conducted joint experiments and exchanged gifts from the two governments. On the 19th, the ships undocked: the Russians returned to Earth on the 21st, while the American crew remained in orbit until the 24th to conduct further experiments. A "universal docking adapter" was developed specially for this mission to enable the two spaceships to dock. It was suggested that this docking module would make space rescues possible (the idea of a "space rescue" had been discussed during the Apollo 13 incident, at which time it was realized there was little, if anything, the Russians could do to rescue an American crew, and vice versa).

Not everyone agreed that ASTP was either a worthwhile expenditure of funds or an appropriate activity for the United States. Some critics were concerned that the Russians would learn too much about American space technology, allowing them to advance in their own technology base. Others simply considered it a very expensive public relations gimmick, and pointed out that the docking module would be useless since ASTP was the final flight for the Apollo command module for which it was designed. The mission did provide Americans access to previously unobtainable information about the Soviet space program. The astronauts and other space officials were allowed to visit the Russian launch center, Tyuratam, where no American had ever been allowed to visit. The astronauts were also allowed to inspect the Soyuz spacecraft, and learned that its technology was similar to that of Gemini, rather than the more sophisticated Apollo hardware. The Russians provided information on the death of the Soyuz 11 crew [3] which had previously been unavailable.

Whether the Russians learned anything new of value or not is difficult to determine. Most technical information about the U.S. civilian space program is widely published, so there may have been little new that they could have learned. The crew and other Soviet space officials were able to spend time at several NASA facilities and contractor sites, however.

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[3] The crew of Soyuz 11 (Georgiy Dobrovolskiy, Viktor Patsayev, and Vladislav Volkov) died of asphyxiation on June 29, 1971 when an improperly sealed hatch allowed the cabin atmosphere to escape during reentry.

VI. Summary

During the fourteen year period, 1961 to 1975, the United States made a total of 31 manned spaceflights, summarized in table 6–1. For the comparable period of time, the Russians made 27 flights, although their manned space program has steadily continued since the last U.S. flight and they now have launched eleven more manned missions. The forty-three U.S. astronauts who made the U.S. space flights accumulated 22,503 hours and 49 minutes of time in space, including 103 hours and 32 minutes of extravehicular activity (EVA) in space, and 162 hours and 13 minutes of EVA on the lunar surface. For the comparable period of time, 34 cosmonauts made 27 space flights, accumulating 10,739 hours and 46 minutes in space, with 2 hours and 24 minutes of EVA time in space and none on the lunar surface. Since the ASTP mission, the Russians have surpassed the amount of time spent in space by U.S. astronauts, and three more cosmonauts have performed EVA. In addition, the Russians have launched three non-Russian cosmonauts, one each from Czechoslovakia, Poland and East Germany, who became the first non-Russian, non-American people to fly in space. (The Russians also have launched the only women into space, Valentina Tereshkova, who flew in space on Vostok 6 in June 1963).

Three American astronauts died as a result of the space program (Grissom, Chaffee and White), while four Russians have died (Komarov on Soyuz 1, and Dobrovolskiy, Patsayev and Volkov on Soyuz 11).

Currently there are 27 astronauts and 35 astronaut-candidates in the U.S. astronaut corps. The astronaut-candidates, who were selected in January 1978 and include six women and four members of minority groups, are presently undergoing a two-year training period, after which they may be eligible for assignment to space flights. Of the 27 astronauts, 16 have yet to make their first space flight. The next manned space opportunities will occur with the space shuttle, discussed in the next chapter.

TABLE 6-1: U.S. MANNED SPACEFLIGHTS

SUMMARY OF MANNED MERCURY MISSIONS

Mission	Launch Date	Return Date	No. of Orbits	Duration (hr:min:sec)	Launch Vehicle	Crew/Comments
Freedom 7 (Mercury-Redstone 3)	05/05/61	05/05/61	Suborbital	00:15:22	Redstone	Crew: Alan Shepard. First American into space (although flight was suborbital).
Liberty Bell 7 (Mercury-Redstone 4)	07/21/61	07/21/61	Suborbital	00:15:37	Redstone	Crew: Virgil Grissom.
Friendship 7 (Mercury-Atlas 6)	02/20/62	02/20/62	3	04:55:23	Atlas	Crew: John Glenn. First American to orbit the Earth.
Aurora 7 (Mercury-Atlas 7)	05/24/62	05/24/62	3	04:56:05	Atlas	Crew: Malcolm Carpenter.
Sigma 7 (Mercury-Atlas 8)	10/03/62	10/03/62	6	09:13:11	Atlas	Crew: Walter Schirra.
Faith 7 (Mercury-Atlas 9)	05/15/63	05/16/63	22	34:19:49	Atlas	Crew: Gordon Cooper. First American to remain in orbit for more than 24 hrs, the ultimate objective of the Mercury program.

Source: Project Mercury: A Chronology. NASA SP-4001.

TABLE 6-1: U.S. MANNED SPACEFLIGHTS (Cont.)

SUMMARY OF MANNED GEMINI MISSIONS

Mission	Launch Date	Return Date	EVA[a] (hr:min)	Mission Duration (hr:min:sec)	Launch Vehicle	Crew/Comments
Gemini III	03/23/65	03/23/65	none	04:52:31	Titan	Crew: Virgil Grissom and John Young. First U.S. two man crew. Manned qualifications of Gemini spacecraft.
Gemini IV	06/03/65	07/03/65	00:36	97:56:12	Titan	Crew: James McDivitt and Edward White. White performed first U.S. extravehicular activity.
Gemini V	08/21/65	08/29/65	none	190:55:14	Titan	Crew: Gordon Cooper and Charles Conrad. Stayed in orbit 8 days to prove man's capacity for long duration space flight.
Gemini VII	12/04/65	12/18/65	none	330:35:01	Titan	Crew: Frank Borman and James Lovell. First manned space rendezvous (with Gemini VI), although no docking was attempted. Gemini VII was passive vehicle.
Gemini VI	12/15/65	12/16/65	none	25:51:24	Titan	Crew: Walter Schirra and Thomas Stafford. First manned space rendezvous (with Gemini VII). Gemini VI was active ship.
Gemini VIII	03/16/66	03/17/66	none	10:41:26	Titan	Crew: Neil Armstrong and David Scott. First manned docking of two ships (with unmanned Agena VIII target). A malfunction occurred in the orbit attitude and maneuver system 27 minutes after docking, forcing the crew to undock from Agena and caused an early termination to the mission. Resulted in first Pacific splashdown, in pre-planned emergency recovery site.
Gemini IX	06/03/66	06/06/66	02:07	72:20:50	Titan	Crew: Thommas Stafford and Eugene Cernan. Performed three rendezvous with Agena IX target, but could not dock because Agena shroud failed to jettison. Cernan performed one umbilical EVA for 2 hrs 7 min.

TABLE 6-1: U.S. MANNED SPACEFLIGHTS (Cont.)

Mission	Launch Date	Return Date	EVA[a] (hr:min)	Mission Duration (hr:min:sec)	Launch Vehicle	Crew/Comments
Gemini X	07/18/66	07/21/66	01:27	70:46:39	Titan	Crew: John Young and Michael Collins. Docked with Agena X target vehicle, and rendezvoused with Agena VIII target vehicle. Collins performed 1 stand up EVA (49 min) and 1 umbilical EVA (38 min) during which he retrieved an experiment from the Agena VIII.
Gemini XI	09/12/66	09/15/66	02:41	71:17:08	Titan	Crew: Charles Conrad and Richard Gordon. Docked with Agena XI target vehicle twice. Gordon performed 1 stand-up EVA (2 hrs 8 min) and 1 umbilical EVA (33 min).
Gemini XII	11/11/66	11/15/66	05:30	94:34:31	Titan	Crew: James Lovell and Edwin Aldrin. Gemini unable to dock with Agena XII target vehicle due to problem with Agena's propulsion system. Aldrin accrued a record amount of EVA time during 3 EVAs: 2 stand-ups of 2 hrs 29 min and 55 min respectively; 1 umbilical for 2 hrs 6 min.

[a] EVA times are computed from hatch opening to hatch closing.

Source: Duration Times -- Gemini Program Flight Summary Report (MSC-G-R-66-5), Jan. 1967. EVA Times -- Carl R. Huss, Chief, Institutional Data Systems Division, Data Systems and Analysis Office, Johnson Space Center, Houston, Texas.

TABLE 6-1: U.S. MANNED SPACEFLIGHTS (Cont.)

SUMMARY OF MANNED APOLLO MISSIONS

Mission	Launch Date	Return Date	EVA[a] (hr:min) Space	Lunar	Mission Duration (hr:min:sec)	Time on Lunar Surf. (hr:min:sec)	Launch Vehicle	Crew[b]/Comments
Apollo 7	10/11/68	10/22/68	none	none	260:09:03	none	Saturn IB	Crew: Walter Schirra, Don Eisele, Walter Cunningham. First U.S. 3-man mission. Tested Apollo command module. First live TV from a manned spacecraft.
Apollo 8	12/21/68	12/27/68	none	none	147:00:42	none	Saturn V	Crew: Frank Borman, James Lovell, William Anders. First manned circumlunar flight; first manned flight of the Saturn V launch vehicle. Accomplished 10 lunar orbits.
Apollo 9	03/03/69	03/13/69	02:08	none	241:00:54	none	Saturn V	Crew: James McDivitt, David Scott, Russell Schweickart. Test of complete Apollo hardware, including docking of command module with lunar module. Schweickart performed EVA from the LM for 1 hr 7 min while Scott did stand-up EVA in the hatch of the command module (1 hr 1 min). Schweickart accomplished first EVA with back pack (was not attached to the spacecraft life support systems through an umbilical, although he was tethered).

TABLE 6-1: U.S. MANNED SPACEFLIGHTS (Cont.)

Mission	Launch Date	Return Date	EVA[a] (hr:min) Space	Lunar	Mission Duration (hr:min:sec)	Time on Lunar Surf. (hr:min:sec)	Launch Vehicle	Crew[b]/Comments
Apollo 10	05/18/69	05/26/69	none	none	192:03:23	none	Saturn V	Crew: Thomas Stafford. John Young, Eugene Cernan. Test of complete Apollo hardware (including docking systems) in lunar orbit. LM descended to within 15 km of Moon.
Apollo 11	07/16/69	07/24/69	none	02:48	195:18:35	21:36:21	Saturn V	Crew: Neil Armstrong, Michael Collins, Edwin Aldrin. First manned landing on the Moon (Armstrong and Aldrin). During 2 hr 48 min lunar EVA, astronauts collected 21 kg of lunar material. Landed in the Sea of Tranquility.
Apollo 12	11/14/69	11/24/69	none	07:46	244:36:25	31:31:12	Saturn V	Crew: Charles Conrad, Richard Gordon, Alan Bean. Second manned landing on the Moon. During 2 lunar EVAs (4 hr 0 min, and 3 hrs 46 min) Conrad and Bean collected 34.3 kg of lunar material. Landed in Ocean of Storms.
Apollo 13	04/11/70	04/17/70	none	none	142:54:41	none	Saturn V	Crew: James Lovell, John Swigert, Fred Haise. Explosion in service module oxygen tank during translunar flight caused mission to be aborted. Astronauts recovered safely.

TABLE 6-1: U.S. MANNED SPACEFLIGHTS (Cont.)

Mission	Launch Date	Return Date	EVA[a] (hr:min) Space	EVA[a] (hr:min) Lunar	Mission Duration (hr:min:sec)	Time on Lunar Surf. (hr:min:sec)	Launch Vehicle	Crew[b]/Comments
Apollo 14	01/31/71	02/09/71	none	09:23	216:01:58	33:30:31	Saturn V	Crew: Alan Shepard, Stuart Roosa, Edgar Mitchell. Third manned landing on the Moon. Shepard and Mitchell landed in the Fra Mauro area, and collected 42.8 kg of lunar material during 2 EVAs (4 hrs 48 min, 4 hrs 35 min).
Apollo 15	07/26/71	08/07/71	00:38	18:35[c]	295:11:53	66:54:53	Saturn V	Crew: David Scott, Alfred Worden, James Irwin. Fourth lunar landing; first use of lunar rover; first live TV coverage of LM ascent from surface. Scott and Irwin landed in the Hadley Apennine region, and collected 76.7 kg of lunar material during 3 EVAs (6 hrs 33 min, 7 hrs 12 min, 4 hrs 50 min). Scott also performed a 33 min stand-up EVA from the LM hatch on the lunar surface. During flight back to Earth, Worden performed umbilical EVA for 38 min to retrieve film packs from the service module, while Irwin performed stand-up EVA to assist him.

TABLE 6-1: U.S. MANNED SPACEFLIGHTS (Cont.)

Mission	Launch Date	Return Date	EVA[a] (hr:min) Space	EVA[a] (hr:min) Lunar	Mission Duration (hr:min:sec)	Time on Lunar Surf. (hr:min:sec)	Launch Vehicle	Crew[b]/Comments
Apollo 16	04/16/72	04/27/72	01:24	20:14	265:51:05	71:02:13	Saturn V	Crew: John Young, Kenneth Mattingly, Charles Duke. Fifth lunar landing, landed in Descartes area. During 3 EVAs, Young and Duke collected 94.3 kg of lunar material. EVA times were 7 hrs 11 min, 7 hrs 23 min, and 5 hrs 40 min. During flight back to Earth, Mattingly performed umbilical EVA while Duke performed stand-up EVA for 1 hr 24 min.
Apollo 17	12/07/72	12/19/72	01:06	22:04	301:51:59	74:59:40	Saturn V	Crew: Eugene Cernan, Ronald Evans, Harrison Schmitt. Sixth and final lunar landing, landed in Taurus-Littrow area. During 3 EVAs (7 hrs 12 min, 7 hrs 37 min, 7 hrs 15 min) Cernan and Schmitt collected 110.4 kg of lunar material. During flight back to Earth, Evans performed umbilical EVA while Schmitt performed stand-up EVA for 1 hr 6 min.

[a] EVA times for the Apollo missions were computed from the time cabin pressure reached 3.0 psi during depressurization and repressurization.

TABLE 6-1: U.S. MANNED SPACEFLIGHTS (Cont.)

[b] Crew is listed in following order: Commander, Command Module Pilot, Lunar Module Pilot. On Apollo 15, 16 and 17, during the flight back to Earth, the command module pilot performed EVA to retrieve film packs from the service module. The lunar module pilot assisted by being in the hatch area, also on EVA. Although the commander also assisted in the transfer of this material, he did not leave the interior of the ship and did not don a biomedical harness (umbilical system), so is not credited with EVA time.

[c] Scott also performed a 33 minute stand-up EVA from the LM, which is not included in this amount.

Source: Mission Duration and Time on Lunar Surface Times: Apollo Program Summary Report (JSC-09423) April 1975. Space and Lunar EVA Times -- Carl R. Huss, Chief, Institutional Data Systems Division, Data Systems and Analysis Office, Johnson Space Center, Houston, Texas.

TABLE 6-1: U.S. MANNED SPACEFLIGHTS (Cont.)

SUMMARY OF POST-LUNAR APOLLO FLIGHTS

Mission	Launch Date	Return Date	EVA[a] (hr:min)	Duration (hr:min)	(Undocked)	(Docked)	Launch Vehicle	Crew[b]/Comments
Skylab 2	05/25/73	06/22/73	05:34	672:50	(19:45)	(653:05)	Saturn IB	Crew: Charles Conrad, Joseph Kerwin, Paul Weitz. First manned mission to occupy Skylab workshop. Performed repairs to the workshop, which suffered significant damage during launch. Remained in orbit 28 days conducting scientific experiments. Completed 1 stand-up EVA (Weitz - 35 min), and 2 umbilical EVAs (Conrad and Kerwin - 3 hrs 23 min; Conrad and Weitz - 1 hr 36 min).
Skylab 3	07/28/73	09/25/73	13:42	1427:09	(11:35)	(1415:34)	Saturn IB	Crew: Alan Bean, Owen Garriott, Jack Lousma. Second crew to occupy Skylab workshop. Remained in orbit for 59 days performing scientific experiments. Completed 3 umbilical EVAs (Garriott and Lousma - 6 hrs 31 min; Garriott and Lousma - 4 hrs 30 min; Garriott and Bean - 2 hrs 41 min).

TABLE 6-1: U.S. MANNED SPACEFLIGHTS (Cont.)

Mission	Launch Date	Return Date	EVA[a] (hr:min)	Duration (hr:min)	(Undocked)	(Docked)	Launch Vehicle	Crew[b]/Comments
Skylab 4	11/16/73	02/08/74	22:25	2017:16	(11:44)	(2005:32)	Saturn IB	Crew: Gerald Carr, Edward Gibson, William Pogue. Third crew to occupy Skylab workshop. Continued scientific experiments during record 84 day stay in space. Completed 4 umbilical EVAs (Gibson and Pogue - 6 hrs 34 min; Carr and Pogue - 7 hrs 3 min; Gibson and Carr - 3 hrs 29 min; Gibson and Carr - 5 hrs 19 min).
Apollo-Soyuz Test Project	07/15/75	07/24/75	none	217:28	(171:42)	(45:46)	Saturn IB	Crew: Thomas Stafford, Vance Brand, Donald Slayton. First docking of two spacecraft from different nations (U.S. Apollo with Soviet Soyuz). Performed joint experiments.

[a] EVA time computed from the time cabin pressure reached 3.0 psi during depressurization and repressurization.

[b] Crew listed in following order: For Skylab -- Commander, Science Pilot, Pilot; for ASTP -- Commander, Command Module Pilot, Docking Module Pilot.

Source: Duration (docked and undocked) Times -- Marcia S. Smith. Program Details of Man-Related Flights. In U.S. Congress. Senate. Committee on Aeronautical and Space Sciences. Soviet Space Programs 1971-1975. Washington, D.C., U.S. Govt. Print. Off., 1976. p. 240.

EVA Times -- Carl R. Huss, Chief, Institutional Data Systems Division, Data Systems and Analysis Office, Johnson Space Center, Houston, Texas.

CHAPTER SEVEN

SPACE SHUTTLE PROGRAM

By Barbara A. Luxenberg
Analyst in Aerospace and Energy Technology

I. Introduction

In 1972, NASA embarked on the major NASA program of the 1970's—development of a space transportation system based on a partially reusable space shuttle vehicle. Now six years later, the program is within a year of the scheduled first manned orbital flight. There are technical problems and funding needs yet to be resolved and testing goals to be reached within the next year, but the concerns surrounding the program at this point have more to do with the operational aspects of the program—how it will be managed, how it will be utilized, and how future space activities can be made productive and economical using the shuttle.

The idea of a reusable space vehicle goes back several decades to the 1940's. However, the development of expendable launch vehicles was so well underway due to the military ballistic missile program, that the concept of a reusable space launch vehicle was not examined in great depth until the budgetary constraints of the post-Apollo era were beginning to be felt. Between 1969 and 1972, NASA considered plans for different configurations of reusable space vehicles. In January 1972, President Nixon gave the go-ahead for development of a partially reusable space shuttle which would form the cornerstone of the space transportation system. The shuttle development program is now nearing its conclusion and shuttle production has started. The first manned orbital flight test (SS-1) is scheduled for September 28, 1979, with the first operational flight (SS–7) to be in February 1981.

II. Space Transportation System (STS) Elements

The partially reusable space shuttle consists of a manned orbiter vehicle, an expendable external propellant tank, and two recoverable solid-fueled booster rockets. The shuttle is to be launched by use of the solid-fueled rockets together with liquid-fueled engines on the orbiter which are fed from the external tank. After launch, the solid rocket booster casings will be parachuted back into the ocean and recovered, and the empty external tank, when released from the orbiter, will be destroyed as it re-enters the atmosphere. The orbiter is able to carry up to 29,500 kilograms (65,000 pounds) of payload into low Earth orbit (185–1110 kilometers, or 100–600 nautical miles). The orbiter can carry a crew of three to seven persons, plus payloads ranging from unmanned spacecraft to fully equipped scientific laboratories, into

orbit for mission durations of up to 30 days. When the mission of the shuttle is completed, the orbiter will return to Earth and land horizontally like an airplane at a speed of about 335 kilometers (210 miles) per hour. Turnaround time to prepare the orbiter for its next mission is optimally planned as two weeks.

The operational STS will eventually include the following elements which are ancillary to the basic shuttle system, but which will increase its capabilities and the kinds of missions it can perform: the Spacelab, a manned space laboratory to be carried in the shuttle cargo bay; the teleoperator retrieval system, a propulsive device to deliver, stabilize, and recover satellites in orbit; the remote manipulator system, an arm-like system for deployment or retrieval of payloads in space; the inertial upper stage, to propel payloads into orbits and trajectories beyond shuttle capabilities; and spinning solid upper stages, to propel payloads into a transfer orbit from which a kick motor could insert them into geosynchronous orbit (22,300 miles or 35,800 kilometers above the Earth).

A. BASIC SHUTTLE SYSTEM

The space shuttle orbiter is designed as a space transport vehicle which can be used for about 100 missions. Its cargo bay is 19 meters by 5 meters (60 by 15 feet) and will accommodate payloads to be orbited or brought back from space. The cargo bay promises a more benign launch environment than that currently available with expendable launch vehicles.

The space shuttle main engine (SSME) is the main propulsion unit for the orbiter and is currently undergoing testing and fabrication by Rocketdyne. The SSME is a high performance, reusable rocket engine burning liquid hydrogen and liquid oxygen. The engine is probably the most challenging technical development effort for the shuttle system, but a National Research Council review of the SSME design in 1978 stated that the engine design was satisfactory and within available technical capabilities.[1] The engine has been tested at rated power, but still needs to achieve 109% of rated power, which certain missions will require. The latest development engine, in flight configuration, has over 5000 seconds toward flight certification requirements. As of October 1978, NASA's official projection is that the SSME will be ready for the first manned orbital flight (SS–1) in September, 1979.

In helping the orbiter achieve the thrust it needs to go into orbit, two solid rocket boosters (SRBs) will be fired. The SRBs, being developed by Thiokol, will burn after ignition until burnout at approximately 50 kilometers (27 nautical miles) above the Earth. Separation will occur, and the SRBs will fall by parachute into the ocean for sea recovery. They will be refurbished for reuse (estimated at 20 times). SRB drop tests have been successfully completed, the development motors successfully fired, and static testing is in progress.

The external tank (ET) is the only component of the basic shuttle system which is expendable. The ET, being developed by Martin Marietta, is designed to contain 1.5 million pounds (68,000 kilograms)

[1] National Research Council. Assembly of Engineering. Ad Hoc Committee for Review of the Space Shuttle Main Engine Development Program. Technical Status of the Space Shuttle Main Engine. In U.S. Congress. Senate. Committee on Commerce, Science and Transportation. Subcommittee on Science, Technology and Space. Space Shuttle Main Engine Development Program Hearings. 95th Congress 2d session, March 31, 1978. Washington, U.S. Gov. Print. Off., 1978. pp. 16–57.

of liquid oxygen/liquid hydrogen propellant. Measuring 47 meters by 8.38 meters, the ET is the largest liquid oxygen/liquid hydrogen structure yet designed for any rocket program. The ET will supply fuel to the SSME and will separate from the orbiter shortly before it reaches orbit. During reentry through the Earth's atmosphere, the ET will be destroyed.

To increase orbital maneuverability, Orbital Maneuvering Systems (OMS) have been developed for the shuttle. An OMS kit consists of two liquid-propellant rocket motors carried in the rear of the shuttle cargo bay. Up to three additional OMS kits can be carried in the cargo bay for use in orbital adjustments, rendezvous operations, and slowing the orbiter down for reentry.

The thermal protection system (TPS) for the orbiter is an extremely important development because it must protect the orbiter from a wide range of thermal and aerodynamic environments and mechanical forces. Four different kinds of materials comprise the TPS tiles, depending on the surface temperatures anticipated for that part of the orbiter structure. Though there have been problems and delays, TPS tile production and installation is now on a schedule which would support the planned orbiter schedules.

Maintaining sufficient weight margins has been a developmental problem for the shuttle system. In order to deliver the maximum of 29,500 kilograms (65,000 pounds) into orbit, and to achieve full mission durations, weight reductions for the orbiter and external tank are required. Plans have been implemented to achieve lower weights so that weight will not be a limiting factor for early orbital operations. However, it appears that strap-on rockets to enhance shuttle performance will be required to launch 14,400 kilograms (32,000 pounds) into a 98 degree inclination orbit from the Vandenberg Air Force Base launch site, a requirement for certain payloads, beginning in 1984. This requirement will necessitate a further reduction in shuttle weight, and methods to achieve this weight reduction and performance augmentation will be studied during FY 79.

Original shuttle planning called for production of five shuttle orbiters. Orbiter 101, the Enterprise, was the first orbiter to be built and was used for the altitude and landing tests in 1977. Due to weight considerations, modifying the Enterprise at this time to fly in space was seen to be more expensive than modifying the structural test article, an orbiter originally intended only for test purposes. Therefore, the Enterprise is currently being used for vibration tests at Marshall Space Flight Center in Huntsville, Alabama and may not go into orbit at all. Orbiter 102, the first orbiter planned for orbital operations, is in the final stages of construction and will be delivered to Kennedy Space Center in early 1979 for launch preparations.

The structural test article (STA) is now being tested for flight at Lockheed's test facility in Palmdale, California, and will be refurbished for orbital operations starting in 1979. The STA is designated Orbiter 099 and is planned to be the second orbiter in space. The Congress has appropriated funds for production of the third and fourth orbiters, for which long-lead production items have started (Orbiters 103 and 104). The need for a fifth orbiter is still under study; although the Congress has approved some funding for long-lead production items, a final decision to produce Orbiter 105 has not yet been made.

B. ANCILLARY ELEMENTS

There are several pieces of hardware being developed for use with the space shuttle to enhance its capabilities and broaden the range of missions it can carry out.

1. Spacelab

The Spacelab (SL) is being developed and built by the member nations of the European Space Agency (ESA). It will be a self-contained laboratory in which scientists can conduct space research in orbit, though all support requirements will be filled by the orbiter. The Spacelab will be carried into orbit in the shuttle's cargo bay and will stay attached to the orbiter during its mission. The present SL design allows missions of up to seven days duration. SL hardware consists of two cylindrical modules (one of which contains support systems) and five exposed experimental pallets. A number of different configurations of modules and pallets can be used depending on the mission.

ESA is developing the Spacelab at its own expense with the understanding that the United States will order a second set of SL hardware from ESA and that ESA will have first chance at any follow-on SL production. ERNO is the prime European contractor for the SL development program. Though some elements of the SL program are behind schedule, ESA is adhering to delivery schedules of August 1979 for the engineering model and initial assembly of the flight unit in late 1978. The SL program has successfully completed its overall system critical design review and there are no major technical problems. The first SL flight is scheduled as the eleventh shuttle mission (SS–11) in June 1981 and will carry a payload designed to verify SL systems and SL-to-orbiter interface, as well as demonstrate the capabilities for scientific research. Payload development for this mission is a cooperative NASA/ESA project.

One matter relating to the SL program which will require resolution shortly is the purchase of the second set of SL hardware. The United States has proposed to ESA that a barter agreement be concluded in which the second SL unit is exchanged for four free shuttle launches, rather than direct purchase by the United States. At the present time, this barter agreement looks doubtful, so NASA may need to find another mechanism to fund purchase of the second set of SL hardware. Currently, there is insufficient money in the NASA budget for this.

2. Teleoperator Retrieval System (TRS)

The TRS is designed to be a multi-purpose space vehicle which will be used for satellite placement, retrieval, and repairs. It will provide an on-orbit capability for a wide variety of future space missions and will be powered by strap-on hydrazine propulsion units. Martin Marietta is building the TRS. The first mission planned for the TRS will be on the second manned orbital flight of the shuttle (SS–2) when it will attempt to either reboost the Skylab space station into a higher orbit for possible reuse, or place it in a controlled reentry configuration.

3. Remote Manipulator System (RMS)

The National Research Council of Canada (NRCC) and NASA agreed to Canadian development of the arm-like RMS for use on the

space shuttle. The RMS program is on schedule, and delivery is planned for July 1979 at Kennedy Space Center. The first RMS flight test is scheduled for the third shuttle mission (SS–3) in 1980. The RMS enables astronauts within the orbiter to deploy or retrieve payloads in space. Canada in developing the first RMS at its own expense, but NASA will purchase any follow-on units which it may require.

4. Inertial Upper Stage (IUS)

The IUS is being developed by Boeing Aerospace Company for the Air Force to take payloads of 2270 kilograms (5000 pounds) from low earth orbit to geosynchronous orbit. It can also be used to launch NASA interplanetary missions. The IUS program is currently under full scale development. NASA use of the first IUS is scheduled for SS–7, which will launch the Tracking and Data Relay Satellite System (TDRSS, see chapter 10) in 1980 or 1981. The first planetary mission to use the IUS will be Project Galileo in 1982.

5. Spinning Solid Upper Stage (SSUS)

The spinning solid upper stages (SSUS–A and SSUS–D) are another means to extend the capabilities of the shuttle. These vehicles will also enable transfer of payloads from low earth orbit to geosynchronous orbit. McDonnell Douglas is developing both forms of the SSUS, which are expendable. The SSUS–A is designed to carry payloads weighing between 1800 kilograms and 2000 kilograms (4000 pounds to 4400 pounds); the SSUS–D to carry small payloads of from 900 kilograms to 1090 kilograms (2000 pounds to 2400 pounds). The first SSUS unit is scheduled for the ninth shuttle flight (SS–9) in 1981 and will carry GEOS–D into orbit. NASA has procured SSUS–As for the SBS and Telesat communication satellite missions. Seven users requiring SSUS launches have paid earnest money to NASA at this time.

III. The STS Program

A. NASA FACILITIES IN SUPPORT OF THE SHUTTLE

Virtually all NASA facilities have been involved in the shuttle program, if only in terms of utilization of the shuttle. However, certain facilities have direct responsibility for the developmental program, and will be involved in shuttle operational management.

The Johnson Space Center (JSC) in Houston, Texas, manages the shuttle program and is responsible for development, production, and delivery of the orbiter. JSC also has been designated as the central ground support facility for the shuttle, but will be assisted by other facilities as necessary. In this central support role, JSC is developing flight plans, conducting crew training, and developing flight control systems engineering.

The Marshall Space Flight Center (MSFC) in Huntsville, Alabama, is responsible for the development, procurement, and delivery of the solid rocket boosters, the external tank, and the orbiter main engines. NASA's National Space Technology Laboratory in Bay St. Louis, Mississippi, is conducting the test firing of the shuttle engines.

Two launch sites are planned for the shuttle: the Kennedy Space Center (KSC) at Cape Canaveral, Florida, for most civilian launches into an easterly orbit, and the Vandenberg Air Force Base (VAFB) in California for launches into polar orbits (which will be predominantly military missions).

Though a General Accounting Office study in 1978 recommended that there be only the Kennedy launch site for the shuttle, NASA, DOD and the State Department dispute the reasoning behind the recommendation, saying that safety, political, security, and economic factors dictate the necessity for both launch sites. The Congress concurred, and both launch sites remain in the program.[2]

The Kennedy Space Center is responsible for design and development of launch and recovery facilities and for operational missions requiring easterly launches. The Air Force is responsible for ground facilities and launch and landing facilities at VAFB for the space shuttle. To minimize costs, common ground support equipment is being procured for both launch sites. In readying ground facilities for the shuttle at KSC, the emphasis has been on refurbishing existing facilities with only limited new construction. Logistical support (maintenance and repair) will be conducted by KSC.

B. CREW

The shuttle astronaut crew consists of the commander, pilot, and mission specialist (who is responsible for the shuttle equipment and resources supporting payloads during flights). The crew may also include one to four payload specialists who are in charge of specific payload equipment for a specific mission. The payload specialists are not NASA astronauts, but will be nominated by the payload sponsor and certified for flight by NASA. NASA has recently named the flight crews for the first four shuttle missions, and has selected thirty five new astronaut-candidates (pilots and mission specialists) for training at JSC and possible selection for future missions.

C. FLIGHT TESTS

In 1977, NASA conducted three series of approach and landing tests for the shuttle using the Enterprise carried atop a modified Boeing 747 airplane. The first series was unmanned, but the second and third series were conducted with a pilot and co-pilot on board. In the third series, the orbiter was released from the 747 and landed on its own. The tests were successful.

The first six shuttle orbital flights will be the Orbital Flight Test (OFT) program. These flights are designed to test shuttle capabilities and systems, and are currently scheduled to begin in September 1979, but that date is a "success target" and may not be met. Operational missions for the shuttle will begin (following the successful conclusion of the OFT program) with the seventh orbital flight (SS–7) now scheduled for February 1981.

D. OPERATIONAL PROGRAM MANAGEMENT

NASA, as a research and development agency, has never managed an operational space program of the magnitude of the space shuttle. It is proceeding with operational planning. and a management instruction defining NASA Headquarters and field installation functional

[2] U.S. Congress. House. Committee on Appropriations. Subcommittees on the Department of Defense. on HUD-Independent Agencies. and on Military Construction Appropriations. Space Shuttle Appropriations for Fiscal Year 1979. Hearing. 95th Congress, 2d session, Mar. 9, 1978. Washington, U.S. Govt. Print. Off., 1978.

responsibilities for STS operations has been issued. An STS operational management implementation plan is currently under review. Management of the shuttle program may have a significant impact on NASA because the agency would, for the first time, have significant operational responsibilities, which may impose new organizational and management requirements within the agency.

A number of different options are available for shuttle operational management other than through NASA, and they are now being studied. One option is for the private sector to manage the shuttle, while another is to establish a separate, new "national space transportation authority" either as a Federal agency or as a public/private agency. A third option would be for an existing user agency, such as the Department of Commerce, Department of the Interior, or Department of Defense, to take on the responsibility of shuttle operations. The advantages and disadvantages of each option will be examined closely by NASA and the Congress during the 96th Congress as the shuttle program moves toward its operational phase.

E. SHUTTLE ECONOMICS AND PROGRAM COSTS

1. Program Costs

Throughout the shuttle development program, there have been technical problems, cost growths, and schedule delays, all of which have resulted in increased funding requirements. The shuttle development program was estimated at its inception in 1972 to cost a total of $5.22 billion (1971 dollars). Allowing for inflation, the total program overrun, over a period of six years, has been 8.5 percent. According to NASA Associate Administrator for Space Transportation Systems, John Yardley, this is not a gross overrun for a program the magnitude of the shuttle development program.[3] Along with cost overruns, problems have been identified in several major project areas, rather than in just one program element, and include the space shuttle main engine, the solid rocket boosters, the external tank, and the thermal protection system.

Problems identified in FY78 will require additional funds in FY79, and the FY79 appropriations are not sufficient to offset the anticipated change in requirements. NASA is consulting with the Office of Management and Budget at this time to decide whether to request a supplemental appropriation for FY79, to stretch out production and development schedules, to reallocate production funds to development, or to defer other NASA missions. As of October 1978, no decision had been made on which would be the best alternative. If funding is not increased in FY79, NASA estimates that the cost of stretching out development and production would be on the order of $1–$1.5 billion.

2. Economics

The shuttle, by virtue of its reusability and the benign launch environment it offers, is intended to lower the costs of conducting space activities. NASA issued an initial shuttle pricing policy in 1977 which gave shuttle launch costs for three categories of users: Department of Defense (DOD) users would pay approximately $14

[3] In transcript of hearings before the House Committee on Science and Technology Subcommittee on Space Science and Applications, September 25, 1978, on NASA Program Review (p. 60 of the transcripts).

million for a dedicated launch (where DOD would use the entire cargo bay); U.S. government civilian users, ESA, and Canada (the latter two because they developed some of the shuttle ancillary elements) would pay about $17 million for a launch; foreign and commercial users would pay about $21 million per dedicated launch.

To a certain extent, the economics of the shuttle depend on the shuttle being used to the optimum extent. Questions have arisen as to whether this initial pricing policy will encourage widespread use of shuttle capabilities, and these policies are currently under review. A major shuttle reimbursement policy, including Spacelab use, payload specialists, the SSUS, the IUS, and "getaway specials" (see below), is currently being developed by NASA. Shuttle reimbursement policy, and its potential impacts, will need to be continuously reevaluated in terms of the operational shuttle program.

F. SHUTTLE UTILIZATION

NASA planning for shuttle utilization is oriented around encouraging government, university, industrial, and international users. NASA is attempting to consider the needs of potential users and to incorporate these needs into the shuttle program and policies. NASA has undertaken many informational activities, such as symposia, to make potential user communities aware of the possibilities available through the space shuttle.

One mechanism NASA has established to encourage shuttle utilization is the small, self-contained "getaway special" payload. For $3,000, a researcher can send up a small payload which does not require orbital support activities, but which merely needs to be taken into orbit and brought back. NASA hopes to involve students and other individuals in space research through this mechanism, and has received earnest money for 252 such payloads already.

Many potential shuttle users may be adopting a "wait and see" attitude toward the shuttle. Resolution of certain issues will be of importance to industrial users before they invest large amounts of money in shuttle utilization. Such questions concern patent rights and rights to industrial processes experimented with on the shuttle. Other questions concern launch scheduling, that is, who has launch priority and whose payloads are likely to be bumped. The costs of conducting repeated experimentation on Spacelab also appear high to many users, perhaps even higher than construction and orbiting of an unmanned satellite to perform the research. NASA is assessing different ways the costs of experimentation on the shuttle can be lowered for the researcher, in the hope of increasing shuttle utilization.

To a certain extent, shuttle utilization will depend on the number of orbiters available, as well as the conviction of potential users of the viability of the shuttle program. NASA does anticipate that shuttle availability will lead to increased utilization, although there are some who question that assumption. Each shuttle is being designed to last for at least one hundred missions over the twelve year operational period. The potential availability of the shuttle is thus high, especially since the turnaround time for a shuttle launch is targeted at two weeks. If the shuttle system were used optimally, it appears that it could handle an average of one shuttle launch every ten to twelve days.

Original shuttle planning called for a 560 mission flight schedule for a five orbiter shuttle fleet, although the revised mission model issued in 1978 anticipates 468 missions between 1979 and 1991. The Carter Administration has questioned the necessity for the fifth orbiter, suggesting that utilization sufficient to require a fifth orbiter will not materialize. The Congress has given final approval to a four orbiter fleet and a decision on the production of the fifth orbiter will probably be made in FY81.

Eventually, the shuttle is supposed to replace all U.S. expendable launch vehicles and would therefore be the only U.S. launch vehicle.[4] However, the Europeans are developing the Ariane launch vehicle which is also planned for flight testing in 1979. The relationship between the Ariane and the shuttle is still unclear. There is some indication that there will be limited competition between the two launch vehicles for certain classes of payloads. Intelsat, for example, is keeping its options open as to whether to launch the Intelsat V series of satellites on the shuttle or Ariane. The viability of the Ariane launcher thus may impact on shuttle utilization.

NASA has developed a plan for orderly transition from expendable launch vehicles to exclusive use of the shuttle for its launches, and expects to phase out Atlas Centaur and Delta launch operations at KSC by the end of December 1980. NASA will preserve backup Delta launch capability for those shuttle users scheduled prior to June 30, 1981. Following the first manned orbital flight, or September 1979, whichever is later, those users must commit either to a shuttle or a Delta launch. NASA has also begun preparation of transition policy for Atlas Centuar class vehicles. Shuttle economies will not be realized in full if an expendable launch capability is maintained in tandem with the shuttle. The Department of Defense will thus be formulating a transition policy for its launches, too, though it may retain expendable capability longer than NASA for reasons of national security.

IV. Future of the Shuttle

NASA is studying the future use of the shuttle and possible developments which would extend its capabilities. One such potential development is a 25 kilowatt power module, which is designed to meet anticipated user requirements for increased power. Power module growth concepts up to 250 kilowatts are also being studied by NASA. Another potential development is a solar electric propulsion stage for planetary missions.

At this time there are no firm plans for specific space shuttle derivatives or follow-on programs. NASA, along with the Department of Defense and the European Space Agency, are studying a number of possible follow-on activities and capabilities, including: construction and operation of large space structures such as communications platforms, solar power satellites, and earth observation platforms; developments leading to in-orbit servicing capabilities as extensions of shuttle capabilities; and future uses of Spacelab and possible Spacelab derivatives.

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[4] The question of whether *all* expendables actually will be phased out is currently under debate at NASA.

What course future planning will take is uncertain at this time. What is clear is that during the near future, the 1980's, the practical application of shuttle capabilities will be stressed, in accordance with the provisions of the President's recently announced U.S. civilian space policy. Recommendations on what future capabilities may be needed by the shuttle will be made by an interagency task force and submitted to the National Security Council's Policy Review Committee (Space) prior to the FY81 budget cycle. Decisions on extensions of shuttle capabilities will be considered in light of emerging national space policy goals at that time.

CHAPTER EIGHT

SPACE LIFE SCIENCES

By Christopher H. Dodge
Specialist in Life Sciences

I. Background

The United States space life sciences effort has a longer history than is readily apparent. For example, long before the National Aeronautics and Space Administration (NASA) was established in 1958, biological payloads had been launched. The first documented suborbital flight carrying a living payload was a V–2 rocket in 1948. The captured German rocket carried a primate, Albert, in a specially designed nose cone. Since that time, there have been more than 60 flights on which biomedical experiments have been conducted, about half of which have been an manned flights. But, between 1974 and 1980, there will have been no biomedical experiments flown on a United States spacecraft. The two most recent United States life sciences experiment were flown on the Russian biosatellites Kosmos 782 and 936 in 1975 and 1977.

In the 1950's and early 1960's, the United States space effort, particularly the manned component, captured the imagination of the public. But as the 1960's came to an end and man had conquered the moon, there occurred a rather sudden downswing in public interest in space affairs. In contrast to manned flights, at no time have biological experiments in space received publicity, and accordingly, little is known by the public about the space life sciences despite a high degree of success achieved by that component of the space effort.

II. Programmatic Organization

The basic objectives of the NASA space life sciences program are: 1) to provide the agency with the basic and applied research and development to assume the medical safety, well being, and life support of all humans involved in spaceflight; and 2) to advance basic knowledge and develop applications of space technology to Earth-bound medical and biological problems and questions by conducting investigations in space.[1]

Many factors come into play in providing for the biomedical support of man in space (Table 8–1). The NASA space life sciences program is designed to investigate these factors in the following fundamental ways: 1) ground-based experiments on plants, animals, and man which, to the greatest degree possible, simulate the conditions of space; 2) experiments on plants, animals, and man in space; 3) instrumentation and hardware development.

[1] Office of Management and Budget. Budget Estimates (NASA). Fiscal Year 1979.

TABLE 8-1

MAJOR FACTORS IN THE MEDICAL SUPPORT OF MAN IN SPACE

1. Atmosphere (gas, pressure, temperature, humidity)
2. Suits
    - Intravehicular
    - Extravehicular
        - Maneuvering unit
        - Communications
        - Portable life support system
        - Hazard protection (see below)
3. Food
4. Water
5. Waste
6. Living conditions and standards aboard
    - Hygiene
    - Schedules
    - Diversions
    - Volume requirements
7. Selection and training
    - Physical, mental, emotional and professional factors
8. Hazard protection
    - Weightlessness
    - Acceleration
    - Noise
    - Vibration
    - Toxic substances
    - Particulate contamination of atmosphere
    - Fire
    - Radiation (electromagnetic spectrum)
        - Selection of orbit
        - Dosimetry
        - Protection
            - Shielding
            - Prophylaxis (drugs)
            - Therapy
        - Micrometeroids
        - Loss of pressure
        - Circadian rhythms
        - Microorganisms
        - Illness
        - Accidental injury
        - Extravehicular hazards
9. Medical monitoring
    - Bioinstrumentation
    - Communications (telemetering versus tape recording
    - Ground support
    - Data collection and processing
10. Mission specific requirements
    - Rendezvous
    - Lunar surface

Source: Vinograd, S. Space Medicine: Scope, Progress, and Applicability to other medical fields. Post Graduate Medicine, Vol. 36, No. 2, 1964. p. 95-102.

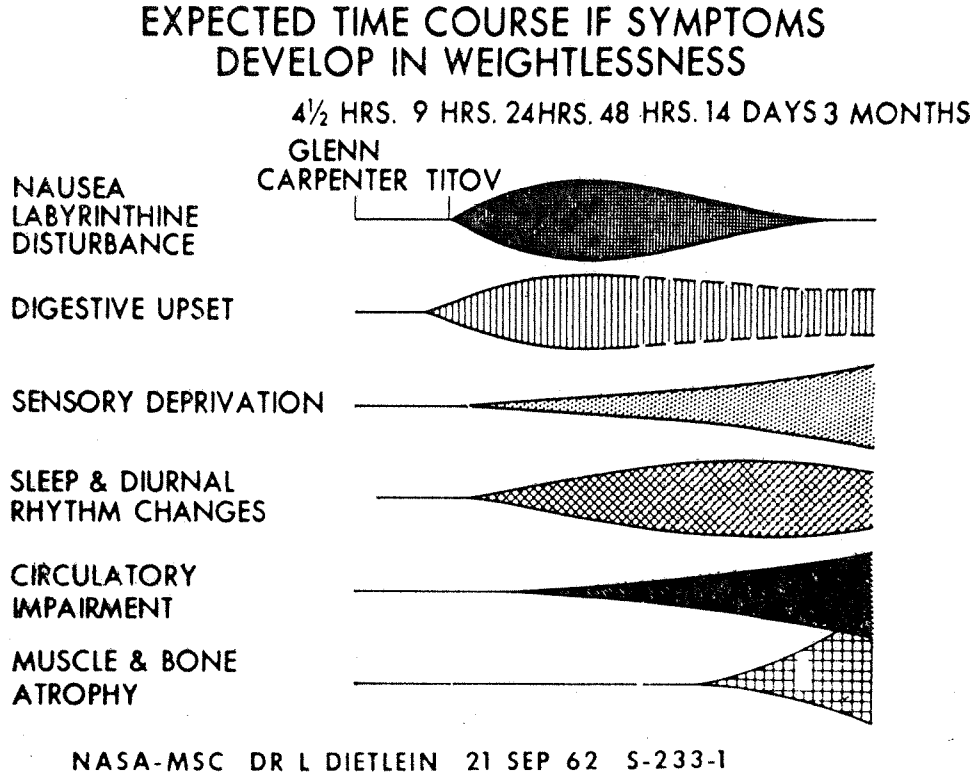
FIGURE 8-1

The basic components of the space life sciences are : 1) space medicine; 2) space biology; 3) planetary protection and containment; and in the near future, 4) closed ecological life support systems.

NASA research and development in the life sciences is designed to be both intra- and extramural, involving virtually every segment of the American scientific community in the universities, industry, and the Federal Government. To date, these resources have contributed to spectacular successes in space, culminating in 1969 in man's successful conquest of the moon and in 1974 in and 84 day stay in Skylab–4, a mark which has been eclipsed by the crew of the most recent Russian space station, Salyut–6.

Whereas in the 1950's, there were serious doubts in some segments of the biomedical community whether man could survive physiologically in space for even one day, it is popular today to discuss the possibility of colonizing space and making journeys to the planets which might take more than a year to accomplish. In early phases of the manned space program, rigorous training and conditioning were necessary precursors to spaceflight. Today, training and conditioning regimens for spaceflight have been relaxed so that many young citizens in all walks of life can look forward with reasonable confidence to the possibility of participating in space programs in their lifetime. While many problems of a physiological nature still remain for man in the space environment (Figure 8–1), approaches to the amelioration of these problems are being developed fairly rapidly so that by the end of this century, man will be able to live in the space environment for up to six months.

FIGURE 8–1



III. Administrative Organization

Before NASA was established in 1958, all spaceflight activities, including the space life sciences, were under military jurisdiction. Space life sciences research activities in the Department of Defense are currently centered in the Aerospace Medical Division of the United States Air Force. Since 1958, the Department of Defense has continued its involvement in bioastronautics programs, but NASA has assumed primary responsibility for manned spaceflight and the space life sciences. In bioastronautics in particular, there is close programmatic and administrative cooperation and coordination between the Department of Defense and NASA.

Within NASA, there have been four major organizations and reorganizations of space life sciences programs since the establishment of the Agency. Initially, the space life sciences were organized under a Committee on Space Life Sciences which became the Office of Life Sciences. In 1966, the Office was fragmented into three entities, the Office of Space Sciences Applications (OSSA), the Office of Advanced Research and Technology (OART), and the Office of Manned Spaceflight (OMSF), each with its own space life sciences component. Toward the end of the 1960's, NASA perceived that there was some inefficiency inherent in that organization so that, once again, the space life sciences were consolidated in 1970, this time under the Office of Manned Spaceflight. In 1975, it was decided that the space life sciences should be a quasi-independent administrative entity, but rather than designating full office status to the discipline, a Division of Life Sciences was formed which existed without approved organization until mid-1978. The Division is now listed officially in the NASA organization under the Office of Space Sciences (OSS).[2]

IV. Funding

Funding for the space life sciences in NASA has enjoyed as tumultuous a history as its organization. The space life sciences budget reached a peak of about $60 million in the mid-1960's, declined to about $20 million in the mid-1970's, increased to $33.3 million in fiscal year 1978 and to $40.6 million in fiscal year 1979. During the decade of declining support for the space life sciences, the proportion of money allocated for manned-space related research remained more-or-less stable while support for basic research decreased precipitously. For example, funding for basic space biological sciences research has fallen below the $1 million/year mark. Only in fiscal year 1979 will it rise above that level slightly. It should also be mentioned that, in addition to the decline in real-dollar funding, inflationary trends have further eroded the purchasing power of the space life sciences dollar.[3]

Parallel with declining funding has been a decreased availability of support for extramural basic and applied research, particularly in the universities. This trend has resulted in the termination and dismantlement of many extramural teams and facilities which had formerly contributed to the successes of space life sciences programs. None-

[2] NASA. Division of Life Sciences (S. Vinograd), 1978. Personal communication.
[3] U.S. Congress. House. Committee on Science and Astronautics. Budget Authorizations (NASA), 1966, 1978, and 1979.

theless, it is worthy to note that over 360 proposals have been received from the life sciences community (56% from universities; 15% from industry; and 18% from Government) as of August 1978 in response to the Office of Space Sciences Announcement of Opportunity for life sciences investigations on space shuttle/spacelab missions. This response is indicative of the continuing interest in the life sciences community in conducting research in the unique environment of space.

After detailed review of these proposals, NASA will develop candidate payloads for the first life sciences Spacelab module. These payloads may include from 20 to 50 different investigations.

CHAPTER NINE

SPACE SCIENCE PROGRAMS

By Marcia S. Smith
Analyst in Aerospace and Energy Technology

Space science can be considered a major factor in the beginning of space flight in a very real sense. The first satellites placed into orbit, both in the United States and the Soviet Union, were designed for space science purposes.

In 1954, a committee was established to make plans for an International Geophysical Year (IGY) to run from July 1, 1957 to December 31, 1958. During this year and a half period, countries throughout the world would participate in various geophysical studies to determine global geophysical properties. The IGY committee recognized that studies of the Earth from orbit might prove immeasurably valuable, and passed a resolution calling for the launch of scientific satellites to support the IGY. In 1955, the U.S. accepted the challenge; a year later, the Russians also accepted. This led to the launch of the world's first satellite, the Russian Sputnik 1, on October 4, 1957 as well as the first U.S. satellite, Explorer 1, on January 31, 1958. Sputnik 1 carried a radio transmitter which, through variations in its two-tone beeping signal, revealed characteristics of the ionosphere as well as changes in its own temperature. Explorer 1 carried a geiger counter which led to discovery of the Van Allen belts of radiation which encircle the Earth, together with micrometeoroid detectors.

Since the IGY, a large variety of space science missions have been launched by the United States and Soviet Union, carrying experiments from even more countries (for example, the Helios solar probes were built by Germany, but launched by the United States). There are a wide variety of vehicles used to conduct space science research, including balloons, sounding rockets, astronomical observatories in airplanes, and unmanned Earth-orbital and deep space probes. For brevity's sake, not all these missions can be discussed here, so the focus will be on the latter categories, which can be divided into two groups: (a) physics and astronomy, and (b) lunar and planetary. (Note that experiments concerning the space *life* sciences are discussed in the next chapter.)

I. Organization for Space Science

There are two agencies in the U.S. Government concerned with civilian science programs involving the planets, starts and other celestial objects: NASA and the National Science Foundation (NSF). The jurisdictional responsibilities of the two agencies in these areas centers on whether the research is to be conducted in space or on the Earth. NSF, for example, has responsibility for ground based telescopes, while NASA deals with space based telescopes, such as the

Orbiting Astronomical Observatory, and the Space Telescope (scheduled for launch in 1983).

The two agencies have a coordinating committee which seeks to prevent overlapping programs and redundant research, for despite the seemingly clear division of jurisdiction, there are some cases in which one agency requests a program that at first glance appears more properly housed in the other. For example, in the FY79 budget, NASA requested funding for a SETI (search for extraterrestrial intelligence) program. Although the program, at least at this stage, involves searches of the stars by ground-based telescopes only, NASA chose to request funding for the program under its broad mandate of "expansion of human knowledge." NASA's lunar sample analysis program came under attack from Congress in the FY79 budget deliberations with Senator Proxmire convincing his Senate colleagues to delete funding from the NASA budget for further activity in this program on the basis that it should be funded by NSF, which has jurisdiction over geological research.[1] A third case involves the construction of an infrared telescope at Mauna Kea, Hawaii by NASA. Although NSF has responsibility for ground-based telescopes, NASA is building this one because it is designed to work in conjunction with spacecraft observations of celestial objects.

Space science programs often encounter difficulties obtaining funding because their benefits are in the basic science area, rather than ones in which there are immediate, tangible benefits, and because of the attitude that these experiments and observations could easily wait until a time when the Federal budget is less constricted. Scientists involved in space science research maintain that the information derived from these studies can have a direct impact on Earth and its environment. For example, studies of the Sun may provide information relating to Earth's climate, and to effects on communication systems. Studies of other planets may prove valuable in understanding conditions which may develop on Earth. For example, Venus, which is very similar to Earth in size and mass, developed an oppressive atmosphere which creates surface conditions vastly different from Earth's. Understanding the reasons why such an environment developed on a planet so similar to Earth may prove vital to Earth's survival.

NASA has maintained an active space science program since its inception, although heavy funding requirements for manned programs, such as Apollo and the space shuttle, led to reduced funding in the space science area.

II. Physics and Astronomy Programs

The physics and astronomy program is designed to provide information on the Earth's space environment, the sun, stars and other celestial bodies. Space missions in this program can be divided into the following groups: the eclectic array of Explorer spacecraft, a variety of orbiting observatories, and solar and interplanetary probes.

[1] Congress finally appropriated $1 million of the $5.7 million NASA had requested for the lunar sample analysis program for FY 79.

A. EXPLORER

The Explorer Program is comprised of many projects and spacecraft, providing the principal means of conducting astronomical studies and long term investigations of the geophysical and near-earth interplanetary environment which do not require large observatories. When large observatories are needed, they are made separate programs, such as the OAO, OSO, OGO and Space Telescope (see below).

Explorer missions can be divided into two subprograms: *Solar-Terrestrial Explorers* which conduct studies of the Earth's near space environment, such as Atmosphere Explorer, Interplanetary Monitoring Platforms, and International Sun Earth Explorer (a cooperative program with the European Space Agency); and *Astrophysics Explorers* which study the stars, galaxies and planets, such as the Small Astronomy Satellites, and the International Ultraviolet Explorer (a cooperative program with the United Kingdom and European Space Agency).

Explorer spacecraft are launched at an average rate of three to four per year. Since 1958, there have been the following classes of Explorer missions: atmospheric, astronomy, ionospheric, scientific, magnetospheric, micrometeoroid, geodetic, and interplanetary monitoring platforms.

The most recent launches in the physics and astronomy program were the International Ultraviolet Explorer in January 1978, and the third and final ISEE (International Sun Earth Explorer) satellite in July 1978. Both the Solar Mesospheric Explorer and the Infrared Astronomical Satellite (a cooperative program with the Netherlands and United Kingdom) are scheduled for launch in 1981. Additionally, NASA has proposed two other explorer series spacecraft, a Cosmic Background Explorer, and an Extreme Ultraviolet Explorer.

B. ORBITING OBSERVATORIES

When larger observatories than those in the Explorer class are required for certain missions, they are approved as separate programs. To date, these have included the Orbiting Solar Observatories, the Orbiting Astronomical Observatories, the Orbiting Geophysical Observatories, and the High Energy Astrophysical Observatories. The Space Telescope is the next planned mission in this series. The advantage of placing these observatories in orbit is that observations from the surface of Earth are restricted by interference of the Earth's atmosphere, which not only distorts images, but filters out certain wavelengths of light.

1. Orbiting Solar Observatory

The principal mission of the Orbiting Solar Observatory (OSO) program was to study solar phenomema difficult or impossible to observe from the ground due to interference of the Earth's atmosphere. There were a total of eight OSOs launched from 1962 to 1975. Among the discoveries made by the OSOs include the information that solar flares have temperatures above 30 million degrees; the solar

polar caps have temperatures of about 1 million degrees celsius, compared to other parts of the solar corona which register about 2 million degrees celsius; the discovery of eruptions of material from the Sun's outer corona which had not been recognized throughout the previous 100 years of scientific eclipse observations; and discovery of high energy gamma rays from the middle of our galaxy.

The final OSO was launched on June 21, 1975 with a primary mission of studying energy transfer mechanisms between different layers of the Sun. Operation of the OSO-8 mission was concluded in the fall of 1978. The studies begun with OSO-8 will be continued by other probes in the future.

2. Orbiting Astronomical Observatory

The Orbiting Astronomical Observatory (OAO) program began in 1959, with final specifications for the first OAO completed in December of that year. OAO-1 was launched on April 8, 1966 carrying x-ray and gamma ray experiments, but after two days in orbit, the satellite suffered a power loss and the mission was lost. OAO-2 was launched on December 7, 1968 and worked successfully for five years, ending operation in February 1973. OAO-2 performed investigations in the ultraviolet range, discovering hydrogen clouds up to a million miles in diameter surrounding comets, observed the first supernova from space, and studied pulsars in the x-ray range. The third OAO mission was launched on November 30, 1970, but the launch vehicle failed and the satellite was not placed into orbit.

The final OAO, called Copernicus, was launched on August 21, 1972 and is still in operation. In 1977, Copernicus made the first unambiguous measurement of heavy hydrogen in interstellar space, an important factor in determining the age of the universe. It has also searched for black holes[2] using its x-ray detectors, and has apparently discovered three.

3. Orbiting Geophysical Observatory

The objective of the Orbiting Geophysical Observatory (OGO) program was to gain a better understanding of the relationship between the Earth and the Sun by conducting a wide variety of physical experiments within the Earth's atmosphere and magnetosphere and in the region between the Earth and the Moon. The program involved launches of two different types of missions, one in a highly elliptical, low-inclination orbit, the other in a low altitude, nearly polar orbit. Three spacecraft of each type were launched alternately one per year between 1964 and 1969. Of the 132 experiments carried on the six OGO spacecraft, 96 were considered successful.

4. High Energy Astronomical Observatory

The High Energy Astronomical Observatory (HEAO) program consists of three separate spacecraft designed to study celestial objects using the x-ray and/or gamma ray wavelengths. HEAO 1 was lanched August 12, 1977; HEAO 2 was launched in November 1978, while HEAO 3 is planned for September 1979. Prior to the launch of

[2] Black holes are thought to be extremely dense collapsed stars with such powerful gravitational fields that nothing, not even light, can escape. Therefore they are invisible except for radiation, such as x-rays, emitted by material as it is sucked into the holes. The existence of black holes is consequently very difficult to prove and to date they remain theoretical. The "discoveries" by OAO and HEAO are not definitive.

HEAO, scientists knew of approximately 300 x-ray sources in the sky; HEAO 1 is discovering about three new x-ray sources each day, and may also have discovered another black hole (see OAO for explanation).

HEAO 1 is a scanning telescope in the gamma and x-ray wavelengths, while HEAO 2 is a pointing x-ray telescope to make more detailed studies of specific objects. HEAO 3 will be similar to HEAO 1, but will concentrate on cosmic gamma ray sources. NASA's proposed Gamma Ray Observatory and Advanced X-Ray Astrophysics Facility would continue research in these areas.

5. Space Telescope

The Space Telescope is scheduled for launch by the space shuttle in 1983 and has a design life of ten to fifteen years. It is a reflecting telescope, capable of accomodating five scientific instruments at a time. Instruments can be changed on orbit by astronauts servicing the telescope from the space shuttle. The Space Telescope will allow astronomers to see objects ten times more clearly than is possible with the best ground-based telescopes.

6. Solar Maximum Mission

The Solar Maximum Mission (SMM) is planned for launch in the fall of 1979 with the objective of making detailed studies of solar flares during the next peak of solar activity (1979–1981). Solar flares have already been studied on the Orbiting Solar Observatories and Skylab, but SMM will investigate the flares over a broader range of wavelengths simultaneously.

The earth-orbital SMM mission will make use of a "multi-mission spacecraft" (MMS) concept in which the basic spacecraft will be standardized for use in other earth-orbital programs. It is hoped that the MMS concept will reduce costs for future spacecraft.

C. SOLAR AND INTERPLANETARY PROBES

Just as the orbiting observatory programs are in many cases extensions of Explorer missions, so are there individual solar and interplanetary probes to make more detailed studies of the sun and interplanetary space than is possible with an Explorer series spacecraft such as the Interplanetary Monitoring Platform. In addition to the programs described below, NASA is considering missions to investigate comets as they travel through our solar system.

1. Helios

Two Helios spacecraft were built by the Federal Republic of Germany and launched by the United States in December 1974 and January 1976 respectively; both are still operating. The probes were designed to traverse the area of space between Earth and the Sun, journeying as close as 0.3 astronomical units near the Sun (44.6 million kilometers).

Each of the probes carry ten experiments to investigate interplanetary space in the vicinity of the Sun, specifically the Sun's corona, solar wind and interplanetary fields and waves, cosmic rays (both solar and non-solar), interplanetary dust particles, and celestial mechanics. Experiments on the two probes are identical, except for inclusion of a

cosmic ray burst detector on Helios 2, but the probes view the Sun from different angles.

2. Solar polar (Out-of-Ecliptic)

A newly approved program in NASA's FY79 budget, the Solar Polar mission, formerly called the Out-of-Ecliptic mission, is a cooperative project with the European Space Agency. The mission calls for two spacecraft to circle the Sun over its poles, out of the plane of the ecliptic (the plane in which the Earth circles the Sun). Because of the enormous energy required to boost the spacecraft out of the ecliptic, the spacecraft will first fly towards Jupiter and use that planet's gravitational force to swing one to the north and one to the south of the plane.

The boost from Jupiter will not only send the spacecraft out of the ecliptic, but will shoot them back towards the Sun where they will fly over the north and south poles of the Sun, areas never before explored. Each spacecraft will carry different experiments to study magnetic fields, sunspots, the solar corona, the "convection layer" deeper in the Sun, and interstellar space. NASA plans to launch the probes from the space shuttle in 1983.

III. Lunar and Planetary Programs

Another part of NASA's space science program is designed to study the Moon and the other eight planets in the solar system (Mercury, Venus, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto) and asteroids. Lunar exploration was necessary prior to manned landings on the Moon and several unmanned projects were undertaken before the first men stepped foot on the lunar surface in 1969. In addition, Mercury Venus, Mars and Jupiter have all been visited by U.S. probes, and mission are now enroute to Saturn and possibly Uranus. NASA is also planning for missions to study the asteroids. The Soviet Union has also had a very active program of planetary exploration, although space considerations do not permit discussion of that program.

A. UNMANNED LUNAR PROBES

The first probes designed to investigate the Moon were of the *Pioneer* series of spacecraft from October 1958 to December 1960. During this time, eight Pioneer spacecraft were launched toward the Moon with the mission of flying past and taking measurements of particles and fields in the Moon's vicinity. Of these, only one was successful, Pioneer IV, launched on March 3, 1959.

The next series of U.S. lunar missions was *Ranger*, designed to transmit close up black and white photographs of the Moon before crashing into the lunar surface. Nine Rangers were launched from August 1961 to March 1965, of which three were successful (VII, VIII and IX).

Surveyor was the next lunar exploration program and this time the probes were designed to land on the surface of the Moon and relay color photographs and other information about the surface, such as the amount of dust (if any) covering the surface to see if it could endanger astronauts. Surveyor III was equipped with a device to dig into the lunar surface so photographs of this material could be relayed

to Earth. Surveyor V carried an alpha-backscattering device which permitted remote chemical analysis of the soil. Five of the seven Surveyors launched between May 1966 and January 1968 were successful.

The last U.S. unmanned lunar probe series was *Lunar Orbiter*, which mapped the Moon's surface to determine where the manned Apollo missions should land. All five of the Lunar Orbiters launched between August 1966 and August 1967 were successful in returning detailed photographs of the lunar surface from low lunar orbit. The Lunar Orbiter program was closely coordinated with the Surveyors so that orbital photographs of a region explored by Surveyor would be available. Lunar Orbiter could return photographs of objects as small as three feet across. Tracking of the spacecraft also revealed information about the Moon's gravitational field.

Following these successful unmanned lunar probes, the Moon was visited by six Apollo crews who returned a total of 841 kilograms of lunar material for analysis. NASA has proposed the next unmanned lunar probe, the Lunar Polar Orbiter, which would photograph the Moon from totally different angles than previously attempted. Requests for funding this program have been denied either by the Administration or Congress for several years, and NASA had indicated that it will no longer submit a request for the program.

B. PIONEER

As mentioned above, several of the first Pioneer probes were designed to investigate the area around the Moon. Other Pioneer probes were sent to look at the Sun and interplanetary space (Pioneer 5, 6, 7, 8 and 9) and these were all successful in their missions.

Pioneer 10 and 11 were the most ambitious of the Pioneer series and both are still operating after many years in space. Pioneer 10 and 11 were the first probes to travel through the asteroid belt and make fly-bys of Jupiter, the largest planet in the solar system. Pioneer 10 was launched on March 3, 1972 and flew past Jupiter in December 1973; Pioneer 11, launched on April 6, 1973, reached Jupiter in December 1974. Pioneer 10 continues to transmit data back to Earth on its way out of the solar system.

Pioneer 11 is enroute to Saturn and is expected to reach that planet in September 1979. In addition to being the first spacecraft to reach Jupiter, Pioneer 11 will be used as a pathfinder for the two Voyager missions (see below).

The Pioneer spacecraft provided enormous amounts of information about Jupiter which in some cases completely changed theories about that planet. Pioneer 10 flew a near-equatorial trajectory, while Pioneer 11 flew a near-polar trajectory, thereby giving a whole-planet view of Jupiter. The spacecraft sent back color photographs of Jupiter, and information on radiation and magnetic fields.

Pioneer-Venus was the last Pioneer mission and involved sending two spacecraft to Venus. The first spacecraft, launched in May 1978, is an orbiter which will remain in Venusian orbit for one year making measurements of the atmosphere. The second spacecraft, launched in August 1978, consists of five separate probes which will enter the atmosphere independently and relay information about the atmosphere

back to Earth before they disintegrate in the Venusian atmosphere. Both spacecraft are scheduled to reach Venus in December 1978.

C. MARINER

There have been ten Mariner spacecraft to date of which three were targeted for Venus (two were successful), six targeted for Mars (four successes) and one for a combined mission to Venus and Mercury (successful). The most significant of the Mariner missions were Mariner 9 which went into Martian orbit in 1971, and Mariner 10 which made repeated fly-bys of Venus and Mercury in 1974.

Mariner 9 was the first spacecraft to go into orbit about another planet and relay pictures back to Earth. The data from Mariner 9 completely restructured scientific thought about Mars. Prior to Mariner 9, Mars was considered to be essentially like the Moon, but Mariner 9 showed it to be a planet covered with what appeared to be dry-river beds and very high mountains. The Viking missions launched in 1975 (see below) continued exploration of Mars based partially on information obtained from Mariner 9.

Mariner 10 provided the first opportunity to look at Mercury close up, and also provide excellent information about Venus, establishing the atmospheric circulation patterns of that planet's massive cloud layers. Mariner 10 made one orbital pass of Venus and three fly-bys of Mercury.

D. VIKING

In 1975, two Viking probes were launched with the purpose of landing on the surface of Mars and making scientific investigations of the Martian soil. Although several missions had been to Mars, none had successfully landed on the surface (two Russian attempts had failed), and this was the first U.S. attempt to land on the surface of another planet. Viking 1 landed on the Martian surface in July 1976 and returned the first photographs of the surface of that planet. Viking 2, which landed in September of that year, also sent back photographs. The two Vikings vastly increased knowledge about Mars, and although one of the missions of Viking had been to search for signs of biological life on that planet, no conclusive evidence was returned by the probes one way or the other.

Each Viking consisted of an orbiter and a lander, so there were a total of two orbiters and two landers. The orbiters carry cameras for photographing the surface of Mars, while the landers carrier a variety of experiments to determine the composition of the Martian soil, including a search for evidence of life there, and to take meteorological readings. The surface is covered by what appears to be iron oxide (rust), giving the planet a reddish hue, something known to Earth bound astronomers for centuries.

Unprecendented information was obtained about Mars from the Vikings, and at last the question of whether Mars' polar caps consist of water ice or carbon dioxide ice (an important factor relating to the possibility of life) was answered: it is water ice. At the present time, one of the orbiters has exhausted its supply of fuel and no longer functions, but the other three spacecraft continue to operate (although some experiments have been shut off, such as the biological experiments) and they have all greatly exceeded their design life.

NASA is now looking into follow-on missions to Viking. Some of the proposals include attempting to return a sample of Martian soil to Earth, or sending another mission to land on Mars, but this time providing it with the capability of movement on the surface (a rover mission).

E. VOYAGER

Formerly called Mariner Jupiter-Saturn, the two Voyager spacecraft were launched in August and September 1977 to fly past Jupiter and on to Saturn. Voyager I will make its closest approach to Jupiter in March 1979, studying both the planet itself and several of its moons. In November 1980, it will make its closest approach of Saturn where it will also study Saturn's largest moon, Titan. Voyager 2 will make its closest approach to Jupiter in July 1979, and reach Saturn in August 1981. At that time, mission controllers may decide to send Voyager 2 on to the next planet, Uranus. Voyager would reach that planet in 1986.

The Voyagers carry a wide variety of experiments in addition to their cameras, including ultraviolet and infrared spectrometers, instruments for measuring planetary and interplanetary particles, and radiation experiments.

F. GALILEO (JUPITER ORBITER-PROBE)

Project Galileo, formerly called the Jupiter Orbiter-probe, is a cooperative program with the Federal Republic of Germany, and is scheduled for launch in January 1982. It will be comprised of two sections, one which will go into orbit around Jupiter, and the other (called the probe) which will enter Jupiter's atmosphere to make measurements of its constituents. The orbiter is designed to remain in orbit for 20 months and will carry 11 experiments, while the probe will carry 6.

CHAPTER TEN

APPLICATIONS SATELLITES

By Lani Hummel Raleigh
Analyst in Aerospace and Energy Technology

I. Communications Satellites

A. INTRODUCTION

The earliest communications satellites were passive, reflecting radio waves back to Earth receiving stations. Echo I, launched on August 1, 1960, was an aluminum-coated Mylar ballon inflated to form a 30-meter (100-foot) diameter sphere.

Echo was followed by a series of low altitude orbiting active relay communications satellites, which amplified the received signal before retransmitting it to the ground. Score, a military satellite launched on December 18, 1958, was the first active communications satellite. Telstar was the first civilian active communications satellite. Launched for the American Telephone and Telegraph Company (AT&T) on July 10, 1962, it transmitted the first live television broadcast from Europe to the United States.

With technical advances in the field of rocketry, more powerful launchers were developed and it became possible to launch satellites into geosynchronous orbit.[1] Each geosynchronous satellite offers the advantage of 24 hour service over approximately one-third of the Earth's surface. Thus, only three satellites are required for global coverage.

There currently is a great proliferation of communications satellites either in operation or in the developmental stages: international commercial communications satellites, aeronautical communications satellites, maritime communications satellites, public service communications satellites, amateur radio communications satellites, and domestic communications satellites.

B. COMMUNICATIONS SATELLITE CORPORATION (COMSAT)

Experiments with early communications satellites indicated their commercial promise and led to discussions in the U.S. Congress on the institutional and financial framework in which the new technology would develop. Alternative proposals for three different types of systems were considered: a government-owned corporation, an all-private corporation dominated by the U.S. overseas carriers, and a hybrid corporation with ownership to be shared by private investors, the U.S. overseas communications carriers, and the U.S. Government. The hy-

[1] At an altitude of 35,800 km. (22,300 miles) above the Earth, the orbital period of a satellite matches exactly that of the Earth, and from the ground appears to be fixed in the sky, or geosynchronous.

brid proposal was adopted and the 1962 Communications Satellite Act created the Communications Satellite Corporation (Comsat). Comsat was to be a "carrier's carrier", providing service principally to international common carriers which in turn would use the satellite circuitry obtained from Comsat to serve the public. Ownership was divided between the public at large and the major U.S. overseas carriers; appointment of several members of the board of directors was made by the U.S. President; and controls and regulatory powers over Comsat by the Federal Communications Commission (FCC) and the Department of State were established.

C. INTERNATIONAL TELECOMMUNICATIONS SATELLITE ORGANIZATION (INTELSAT)

Shortly after its formation, Comsat officials and appropriate U.S. Government agencies, acting under a congressional mandate to establish an international communications satellite system, began negotiations for the establishment of an international organization to develop and manage a global commercial communications network. As a result of several years of international negotiation, the agreements establishing interim arrangements for a global commercial satellite system entered into force August 20, 1974.

Under the interim agreements, the United States dominated the organization with 61% of the votes and Comsat as the designated manager, responsible for the design, development, construction, establishment, operation, and maintenance of the space segment.

Dissatisfaction grew with the interim arrangements and negotiations began to develop definitive agreements. In February 1973 the defintive agreements entered into force, forming the basis of Intelsat's present structure and operation. This reorganization of Intelsat witnessed a diminishing of U.S. power within the organization. Currently, no nation is permitted more than 40 percent of the vote. In addition, Comsat now functions under a six-year "management services contract" with specified technical and operational duties. Beginning in 1979, Intelsat may choose management contractors other than Comsat.

Since the launch of Intelsat I (Early Bird), the world's first international commercial communications satellite on April 6, 1965, capacity of the system has grown from one satellite offering 240 circuits to an integrated network which provides a combined capacity of 20,000 circuits and 8 TV channels. Membership has expanded from 11 to 102 nations. The system has achieved a reliability of 99.9 percent. User charges have been drastically reduced, yet Intelsat continues to give a 14 percent return on member investment.

D. AERONAUTICAL COMMUNICATIONS SATELLITE (AEROSAT)

Aerosat was a joint United States-European-Canadian program to develop an aeronautical communications satellite system for an improved transoceanic communications link between aircraft and air traffic control centers.

The increasing congestion and predicted saturation of the High Frequency (HF) band for aeronautical communications prompted the airlines and various government agencies to examine transoceanic

communications systems. Consensus centered on a communications satellite as an effective solution to the communications problem. In order to avoid a fragmentary approach and competing technical designs, European cooperation was sought in the development of an aeronautical communications system. After lengthy negotiations, a joint Memorandum of Understanding was signed in 1974. The agreement provided for a Joint Aerosat Evaluation Program to determine the requirements of an operational system.

Beginning in 1974, the Aerosat program experienced technical delays, rising costs, increasing dissatisfaction from the user community, contract disputes, and congressional disenchantment. Finally, in the spring of 1977, all funds for Aerosat R&D were deleted from the Federal Aviation Administration FY78 budget with orders that the program be reevaluated and less expensive alternative communications systems be considered. Thus far, no alternative system has been proposed.

E. MARITIME COMMUNICATIONS SATELLITES

1. Marisat

Despite the growth in maritime communications traffic and the dramatic increase in global commercial shipping tonnage, prior to the launch of Marisat 1, mariners still relied on communications techniques essentially unchanged over the past 75 years—medium and high frequency (MF and HF) radio, and Morse code telegraphy. The result of using these outdated means of communications was hours of delay, congested frequencies, poor quality communications, and unreliable transmission depending on weather and atmospheric conditions. The U.S. Marisat system now provides fast and dependable communications, unaffected by weather or ionospheric conditions, 24 hours a day.

The Marisat system is a joint venture of Comsat General Corporation, RCA Global Communications, Western Union International, and International Telephone and Telegraph. Originally planned to fill a gap in the Navy's communications satellite program, the Marisat system evolved into a shared military/commercial system. The three Marisat satellites in the system were launched in 1976 and provide voice, data, facsimile, and telex services.

2. Inmarsat

The need for an international organization to own and operate a global communications system for maritime communications was discussed by the International Maritime Consultative Organization (IMCO) as early as 1966. After ten years of negotiations, a convention establishing an International Maritime Satellite System (Inmarsat) was opened for signature on September 3, 1976.

Two agreements must be signed: a convention presenting the broad policies of the organization and its structure to be signed by the United States and other participating governments, and an operating agreement to be signed by the U.S. designated entity.

Congressional efforts to enact legislation in the 95th Congress to specify Comsat as the U.S. designated entity culminated in the passage of the International Maritime Telecommunications Act. Passage of the Act was important because nations representing 95% of the initial investment must sign the documents by July 3, 1979. Since the United States has a 17% share, its failure to specify a designated entity to sign

the operating agreement could have blocked the establishment of Inmarsat.

F. PUBLIC SERVICE COMMUNICATIONS SATELLITES

Most commercial satellite communications are handled by common carriers who integrate their space communications into their existing ground networks. The satellite provides a long-distance link, with local and regional service handled by ground link. Since a heavier payload necessarily increases the cost of the launch, it is to the economic advantage of the carriers to use a simple, relatively light-weight satellite, and place the heavy technical burden on a few large and expensive regional ground stations. Such a communication system serves efficiently the easily accessible, heavily populated areas of the world. There are, however, many remote, sparsely populated areas for whom terrestrial communication links are physically impossible or economically prohibitive. In addition, there are many communications users in such areas as education, medicine, counseling, and public safety who cannot afford or do not require a large dedicated Earth station.

These users require a system transferring the burden of the satellite communications network from the Earth station to the satellite. This is accomplished by increasing the satellite transmission power as well as its ability to focus this power. Thus, unlike conventional satellites which transmit moderately powerful broadcasts over large geographical areas, the public service communications satellites deliver high power transmissions to relatively limited areas. The resultant decrease in the cost and the complexity of the receiver stations places satellite broadcasting into the budgetary grasp of the small, independent user and opens the door to a wide variety of public service broadcasts by satellite.

When it was launched into geosynchronous orbit on May 30, 1974, the Applications Technology Satellite–6 (ATS–6) was the most powerful communications satellite ever developed. ATS–6 was the first spacecraft with transmitting power to broadcast directly to small and simple ground receiving units in remote regions covering large geographical areas. Since its launch, ATS–6 has served an international community as a special broadcasting station in space.

For the first year of operation, ATS–6 was used primarily for health care and educational experiments in the Rocky Mountain region, the Appalachian States, and the States of Washington and Alaska. Approximately one year after launch, ATS–6 began a year-long cooperative experiment with the Indian Space Research Organization (ISRO) to evaluate the role of television by satellite in promoting rural development. After the Indian experiment, NASA and the Agency for International Development (AID) embarked on a joint venture to use ATS–6 to demonstrate to 27 developing nations how space technology could improve their ways of life.

The Canadian Communications Technology Satellite (CTS), a joint United States-Canadian effort, was launched in 1976. Based on ATS–6 technology, it too is a powerful satellite designed to operate with simple ground equipment. However, unlike ATS–6 which broadcasts in the four and six gigahertz (GHz) bands, for the past two

years CTS has been used for health care, educational, and teleconferencing experiments in the higher 12 GHz band.

With the expected demise of both ATS–6 and CTS, public service communications users have begun to explore the possibilities of leasing service from commercial satellite carriers.

One of the principal concerns of the public service communications user is the aggregation of the user market in order to reduce the cost of satellite communications. The Public Service Satellite Consortium (PSSC), established in March 1975, was created to permit its members to provide their respective public services more effectively at less cost. The purpose of a consortium lies in its ability to aggregate a large number of small diverse users into a market group that can then share the financial risks and take advantages of economies of scale in planning, procurement, and operations. Originally funded by nominal member fees and a founding grant from the U.S. Department of Health, Education, and Welfare and NASA, the PSSC plans to become self-supporting through fees for the provision of coordination services for experiments, technical support for experiments, and analysis of user requirements in terms of technology, financing, and organization.

G. ORBITING SATELLITE CARRYING AMATEUR RADIO (OSCAR)

The OSCAR (Orbiting Satellite Carrying Amateur Radio) satellites are designed and constructed by radio amateurs on a nonprofit, nongovernmental basis. They ride piggyback into orbit during launches of scientific or communications satellites, replacing the dead weight ballast ordinarily used to balance the weight of the uppermost booster stage.

OSCAR 1, launched on December 12, 1961, was the first nongovernmental satellite. OSCAR IV relayed the first direct satellite communication between the United States and the Soviet Union, The most recent satellite, OSCAR 8, was launched in March 1978.

Participation by amateurs is international in scope. OSCAR 5 was designed in Australia and portions of OSCAR 8 were constructed in Japan. In addition, there are currently operators in more than 100 countries actively transmitting and receiving signals through the various OSCAR satellites.

H. DOMESTIC COMMUNICATIONS SATELLITES

Domestic communications satellite systems were first proposed in the early 1960's. However, controversy over the number and ownership of such systems prevented their establishment until 1972 when the Federal Communications Commission (FCC) issued its policy on domestic communications systems. In accordance with this policy, three systems were authorized beginning in 1973: the Westar system, the Comstar system, and the Satcom system. A fourth, the Satellite Business System, was authorized in 1977.

Western Union launched the first U.S. domestic satellite, Westar, in April 1974. There are currently two Westar satellites in operation. The Westar communications capability is used for transmission of television, telex, and teletype. The Advanced Westar communications relay satellite, to be launched in the early 1980's, will continue these services and will add a digital transmission capability.

The American Telephone and Telegraph Company (AT&T) and the Communications Satellite Corporation (Comsat) were authorized to establish a system exclusively for switched telephone traffic carried by the Bell System. Thus far, three Comstar satellites have been launched, beginning in 1977.

The RCA Satcom, first launched in 1975, provides video distribution, data, and telephone service. Currently, there are two Satcoms in operation.

A fourth system, the Satellite Business System (SBS), was authorized in 1977. It will be operated jointly by IBM, Comsat and Aetna Insurance, and will be used largely for data transmission, computer interconnection, and corporate telephone service. The first SBS satellite is scheduled for launch in 1984.

II. Meteorological Satellites

Early successes in photographing the atmosphere and cloud formation were achieved soon after World War II. German V–2 rockets launched from White Sands, New Mexico, in 1947 gave early indications of the feasibility and utility of such operations. The Television and Infrared Observation Satellite, TIROS, the first U.S. weather satellite, was launched on April 1, 1960. Imagery from TIROS–1 gave meteorologists the first total view of weather patterns.

Since 1960 weather satellites have undergone rather dramatic technical and conceptual changes. Satellites, control systems, orbital configurations, sensors, and data processing and handling systems have been modified, improved, and augmented by newly developed concepts or equipment.

An operational meteorological satellite system was inaugurated in February 1966 with the launch of the first operational weather satellite. Administratively, the new system was managed by the National Environmental Satellite Center (NESC) of the Environmental Satellite Services Administration (ESSA) in the Department of Commerce. In operating the National Operational Meteorological Satellite System (NOMSS), NESC was responsible for: command and control of the satellite in orbit, satellite data acquisition and processing, data dissemination, data archival, maintenance and improvement of ground data handling systems, future spacecraft system plans, coordination with NASA for the development of new and improved sensor systems, and the procurement of spacecraft, launch vehicles, and launch services. It was also a function of NESC to conduct research and development in the analysis and application of satellite data, Satellite technology research and development as well as satellite launches were to remain the responsibilities of NASA. In 1970 the National Oceanic and Atmospheric Administration (NOAA) assumed the responsibilities of the now defunct ESSA.

The development of the geostationary weather satellite, first launched in 1974, represented a great advance in meteorological satellite capability. Although it is incapable of viewing the polar regions, the advantage of its geosynchronous orbit is that it is relatively immobile in relation to the Earth's surface and can therefore provide continuous coverage of the same portion of the globe. Continuous coverage is particularly significant for the detection and tracking of severe storms which are small in size and transient in nature.

The United States participates in international meteorological programs through the World Meteorological Organization (WMO). The WMO is a specialized agency of the United Nations which was established in 1951. It was formed in order to establish, coordinate, and improve meteorological services throughout the world. U.S. meteorological satellites, both polar-orbiting and geostationary, contribute to this effort. WMO members obtain access to meteorological information from U.S. weather satellites indirectly through a WMO network of international, regional, and national meteorological centers, and directly from automatic picture transmission (APT) receiving sets.

III. Earth Resources and Environmental Monitoring Satellites

A. LANDSAT

Early in the U.S. manned space flight program, astronauts using handheld cameras photographed the Earth from the windows of their spacecraft. Concurrently, new types of high altitude imagery using multispectral scanners were developed and tested using aircraft. These two activities resulted in a concept of a new global data acquisition system consisting of a multispectral scanner mounted on a satellite observation platform, a concept that was ultimately to become Landsat.

Landsat 1 was launched on July 23, 1972, followed by Landsat 2 on January 22, 1975. Both satellites were operational until January 1978 when Landsat 1, having outlived its design life by four and one half years, was finally retired. Landsat 3 was launched on March 5, 1978. A fourth, yet more technically advanced Landsat, is currently under development.

Landsat satellites orbit the Earth at an altitude of 917 kilometers (570 miles) approximately once every 103 minutes, or 14 times a day. Like Landsat 1, Landsat 2's electronic sensors, or multispectral scanners, measure the radiant energy reflected from the Earth's surface in four different wavelength bands. Two bands measure visible light radiation and two measure infrared and ultraviolet radiation. Different materials on the Earth's surface absorb and reflect sunlight differently. Thus, it is possible to identify these different materials by their spectral signatures, or manner in which they reflect light. The multispectral scanners measure this reflected energy and send these measurements to the Earth in the form of digital data.

In addition to four light-sensing channels, Landsat 3 carries a fifth "thermal" (heat measuring) channel on its multispectral scanner. The detection of temperature differences in vegetation, bodies of water, and urban areas is expected to yield significantly improved data for agricultural and land use studies. Other sensor improvements have reduced the minimum-sized area for which the sensor data can be analyzed from 80 meters to 40 meters. Thus, areas as small as half an acre can be identified and studied.

The accuracy of the satellite techniques are, for the most part, dependent upon good supporting surface measurements (ground truth). The satellite information generally cannot stand alone without good ground truth data. The advantage of satellite imagery is not in the

replacement of in-situ supporting measurements, but in the generalization of these measurements to areas so vast (country or regional scale) that no conventional technique can provide the integrating information at less than exorbitant costs. In addition, Earth resources satellites can provide broad synoptic views of large areas of the Earth under uniform lighting conditions. Interpretation of satellite data is also less time-consuming than the interpretation of data derived from traditional survey techniques. This increase in the speed of data interpretation and the additional advantage of repetitive coverage enable the user to effectively monitor such constantly changing phenomena as crop growth and condition.

Experiments with Landsat data have demonstrated its usefulness in the fields of agriculture, hydrology, geology, cartography, land use, environmental monitoring and marine and ocean resources. Landsat imagery has been used to determine crop yield and condition, to estimate snowmelt, to map major crustal faults in the Earth's surface, to revise maps, to define land use, and to detect certain types of pollution.

B. HEAT CAPACITY MAPPING MISSION (HCMM)

The Heat Capacity Mapping Mission (HCMM) is the first of a series of low-cost, modular design spacecraft built for the Applications Explorer Mission (AEM)—small experimental spacecraft in special orbits to satisfy mission-unique experimental data acquisition requirements. Launched on April 26, 1978, HCMM travels in a circular, sun-synchronous 620-kilometer (385-mile) orbit. The spacecraft is unique in that its day-night heat measurement sequence permits readings of temperature changes associated with solar heating during the daytime and radiative cooling at night. The mission was designed to allow scientists to determine the utility of such information in conjunction with Landsat data for discrimination of various rock types and location of mineral resources, measuring and monitoring surface soil moisture, measuring plant canopy temperatures to determine plant stress, studying urban heat islands, and deriving information from snow fields for water runoff prediction.

C. STEREOSAT

The Stereosat mission, as approved by Congress in NASA's FY79 budget, will utilize dual telescope and sensors to provide high resolution black and white three-dimensional stereoscopic imagery in digital form. Stereoscopic imagery will enable the delineation of linear features and characteristics of low relief areas which will permit interpretation and measurement of terrain and slope, primarily for purposes of petroleum exploration. A launch date for Stereosat has not been announced.

IV. Ocean Dynamic Satellites (Seasat)

In view of the influence of the world ocean on global atmospheric circulation patterns, a need was perceived for a satellite that could monitor key features of the many processes involved in the interacting air, sea, and ice components of the climatic system. Seasat 1 was a "proof-of-concept" mission to determine if microwave instruments scanning the oceans from space could provide useful scientific informa-

tion on surface winds and temperatures, currents, wave heights, ice conditions, ocean topography and coastal storm activity.

Launched on June 26, 1978, Seasat circled the Earth 14 times a day and its instruments scanned 95% of the oceans' surface every 36 hours, providing scientists with their first synoptic observation of the oceans. Low flying aircraft, ships and instrumented buoys also took measurements to corroborate Seasat data. The satellite failed in orbit in October 1978.

During its feasibility study phase of Seasat in early 1973, NASA sought the involvement of the oceanographic community to assure that Seasat would be designed for its users. Thus, NASA solicited user input from a variety of public and private institutions. By initiating a wide range of commercial and government agency involvement in Seasat from the start of spacecraft operations, NASA hoped to avoid being in the position of forcing the development of an operational system. Rather, the expectation is that the operational system will be developed by the user community. For this reason, NASA formulated an industrial users' program that could result in limited but direct commercial application of Seasat data shortly after its June 1978 launch. Under the plan the users were to support the cost of the research program at their field sites, while NASA's primary obligation to the program would be to obtain the Seasat data and provide it to the user in a suitable format. Thus, Seasat data was received by NASA's space tracking network station at Fairbanks, Alaska and then sent to the mission operations control center at the Goddard Space flight Center. The data was then sent to the Jet Propulsion Laboratory for distribution to researchers. As the data were received at the NASA ground station, they were simultaneously retransmitted via commercial communications spacecraft to the Navy Fleet Numerical Weather Center in Monterey, California. The Navy facility then relayed them in real time to industrial users.

Under the plan, the users were to evaluate the data in the context of specific requirements for a period not to exceed two years. After the two-year period, NASA planned to stop supplying the data free, but the users could continue to obtain data via reimbursement arrangements that would be made later.

As a follow-on to Seasat, NASA, the Department of Defense, and the National Oceanic and Atmospheric Administration will participate in a quasi-operational National Oceanic Satellite System (NOSS). The program would involve two spacecraft launched by the space shuttle starting in 1984. NOSS is a candidate for initial development funds in NASA's FY 1980 budget, now being negotiated with the Office of Management and Budget.

If Seasat had functioned for three years (two years beyond its design life), there would have been a two-year gap in data until a Seasat B could be launched. Now, with the failure of Seasat 1 and no backup satellite, this gap has widened considerably. Although there have been discussions of adding one or more Seasat-type instruments to Air Force Defense Meteorological Satellite Program (DMSP) spacecraft to fill the Seasat data gap, there have been no firm proposals. The failure of the Seasat spacecraft calls into question the advisability of making large investments in ground equipment and orbiting a spacecraft without a spare.

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V. Earth Dynamic Satellites

A. GEOS SATELLITES

Since the advent of satellites, man has made much progress in refining his knowledge of the size and shape of the Earth. The second U.S. satellite (Vanguard 1, March 17, 1958) determined the pear-shaped component of the Earth during the International Geophysical Year (IGY).

The particular objectives of the NASA program in satellite geodesy have been to provide a precise measurement of the Earth's surface and a mathematical description of the Earth's surface and its gravity field. These objectives formed the basis of the National Geodetic Satellite Program (NGSP) initiated in 1964. Under this program five dedicated geodetic satellites have been launched: Geos 1, 2, and 3, which carry laser, radio doppler, and radar tracking equipment; PAGEOS, a passive aluminized mylar balloon for optical sighting by reflected sunlight; and, LAGEOS, the first NASA satellite dedicated exclusively to laser ranging.

Major activities conducted under the NGSP program include: the development of improved models of the Earth's gravity and magnetic fields, the development of techniques for the detection and management of tectonic plate motion and crustal deformation, and the application of new systems for geodetic surveying and topographic mapping. While the techniques and approaches used in these studies are unique, the questions addressed are fundamental problems in geophysics and geodesy, and in many cases relate to the operational roles of other agencies such as the U.S. Geological Survey, the National Geodetic Survey, and the Department of Defense. Among the practical benefits expected from the NGSP program are: contributions to the assessment of potential resource areas, to the forecasting of catastrophic events such as earthquakes, and to the better understanding of the physical character and dynamic motions of the Earth.

B. MAGSAT

The Magnetic Field Satellite (Magsat) is expected to chart the Earth's magnetic fields to aid in the development of magnetic charts for navigation and anomaly maps for natural resources assessment. The launch date was moved from 1980 to 1979 in order to support the U.S. Geological Survey's requirement to update magnetic field charts every five years.

C. GRAVITY FIELD SATELLITE

NASA is completing conceptual studies of a Gravity Field Satellite for global gravity measurements.

VI. Navigational Satellites

The basic concept that led to the development of navigation satellites dates back to the launch of Sputnik I in 1957. Scientists who were monitoring Sputnik signals noted that when the transmitted radio frequency was plotted graphically, a characteristic curve of doppler shift appeared. By studying this apparent change of radio-wave fre-

quency from the satellite as it passed, they were able to show that the doppler curve, when properly used, described the orbit of the satellite. They further discovered that by monitoring a single pass, all of the orbital parameters for a satellite could be determined. In 1958 a satellite navigation system based on measurement of the doppler shift of a satellite's radio frequencies was proposed.

A. TRANSIT

The first Navy Navigation Satellite System (NNSS), Transit, was launched in 1959. It was made available for commercial use by Presidential directive in July 1967, and declared fully operational in 1968.

Transit utilizes six continuously broadcasting satellites in polar orbits in different planes. Tracking stations track passing satellites and relay data to the computer centers, where it is used to compute future orbits. These orbital predictions are included in satellite injection messages and sent to injection facilities. Every 12 to 16 hours these facilities transmit messages to satellites where they are stored in memory. Satellites broadcast their current known position in successive 2-minute data readouts as they orbit the Earth. Navigation sets aboard ships use the known satellite position and doppler observations of the incoming satellite broadcast to fix their positions.

Accuracy is supposed to be to one tenth of a nautical mile, but fixes can only be obtained when a satellite is in view and generally above 15 degrees elevation from the ship. This occurs approximately every 90 minutes, with a longer interval at low latitudes and a shorter interval at high latitudes.

B. NOVA

Advanced versions of the Transit navigation satellite, Nova, are scheduled for launch beginning in 1979. The Nova satellites will provide faster and more accurate position fixes than the present spacecraft and will be provided with on-board station-seeking and station-keeping propulsion systems for greater orbit maintenance. Nova satellites will also require fewer position updates from ground stations.

C. NAVSTAR GLOBAL POSITIONING SYSTEM (GPS)

The Navstar Global Positioning System (GPS) is a space-based radio navigation system designed to provide users with continuous world-wide three-dimensional position and velocity information. GPS will consist of three segments: (1) a space segment which will comprise satellites broadcasting extremely accurate satellite position coordinates and timing information to users around the globe, (2) the user segment, which will process the time and position information from four satellites to obtain accurate position and velocity components, and (3) the control segment which will monitor the 24 satellites and update their position coordinates and timekeeping mechanisms.

The space segment will ultimately consist of 24 satellites, in three planes in circular orbits. The satellites will continuously broadcast on two radio frequencies, providing satellite identification and navigation data to be processed by the GPS users' receivers. On being activated, the user's set automatically will select the four satellites most favorably located, lock onto their navigation signals, and compute

the approximate range to each. It then will form four simultaneous equations involving the user's position and the time factor. Position determination is expected to be accurate to within ten meters.

The accuracy of this type of position location system depends heavily on the ability to measure radio signal travel time and requires precision clocks. The first two experimental passive ranging navigation satellites, TIMATION I and II, launched in 1967 and 1969, experimented with quartz crystal standards. The need for more accurate clocks was recognized and in 1974 Navigation Technology Satellite One (NTS–1) was launched. It used a rubidium atomic clock. NTS–2, the first of the six satellites in Navstar's vailidation program, was launched in June 1977, and was used in the first true test of the Navstar GPS concept. In 1978 three Navstar satellites, Navstar 1, 2, and 3, were launched as a continuation of the validation phase. If the Department of Defense decides to proceed with the program, a six satellite Navstar GPS system should be operational by the late 1980's.

At present the Navstar GPS program is a multiservice Department of Defense effort designed to meet the future navigational requirements of the armed forces. Although civilian uses of the system are also under consideration, no formal policy has been established to ensure civilian access to the system.

VII. Tracking and Data Relay Satellite System (TDRSS)

NASA's Tracking and Data Relay Satellite System (TDRSS) will consist of two specialized communications relay satellites in geosynchronous orbit and a ground terminal located at White Sands, New Mexico. With the existing network of ground satellites, most low orbiting satellites are usually out of the sight of any station. The TDRSS system will increase the present 15 percent coverage provided by ground stations to 85 percent. Data will be relayed directly to and from the spacecraft and mission control centers, eliminating the need for costly and often unreliable recorders which currently store data on orbiting satellites until they are in view of a ground station.

Each TDRSS satellite will be capable of simultaneous tracking and two-way communications with 20 or more satellites and manned spacecraft in Earth orbit at altitudes up to 5,000 kilometers. The system will offer an increase in wideband facilities to handle the high data rates needed for the large quantity of data from Landsat-D, Spacelab, and the space shuttle. Thus, TDRSS will enable NASA to phase out nine of its thirteen world-wide tracking stations, and to avoid the massive network update which would have been required to handle the wideband communications of future space missions.

NASA chose to lease TDRSS system services from Western Union rather than purchase its own system. A major factor in this decision was an estimated cost savings with the lease option resulting from deferred expenditures.

Another major factor in providing a lower-cost system is the shared spacecraft concept. There will be a total of four operational TDRSS spacecraft in geosynchronous orbit. Two will be assigned to the NASA mission; the other two will be stationed so they can serve Western Union's domestic users. One of these will usually be operated in a shared mode, serving both.

The first TDRSS spacecraft is scheduled to be launched by the space shuttle in late 1980.

VIII. Search and Rescue Orbiting System

The objective of the Search and Rescue Orbiting System is to demonstrate the feasibility of satellites to provide a significant improvement in the capability for search and rescue forces to detect and locate distress signals from general aviation aircraft and marine vessels during emergencies. In 1974, Congress passed legislation requiring the installation of emergency locater transmitters (ELT's) on general aviation aircraft, and the U.S. Coast Guard in 1975 required the installation of emergency position indicating radio beacons (EPIRB's) on ocean going vessels. At present, the "home in" range of these instruments is within 30 miles of the crash site, usually achieved by flying criss-cross patterns involving many planes and costly, sometimes risky, flying hours.

NASA, with the support of the Federal Aviation Administration (FAA), the U.S. Coast Guard, the Department of Commerce, Federal Communications Commission, and the U.S. Air Force, has proposed a satellite system to aid search and rescue efforts. The proposed satellite system would consist of instrument packages to be carried by two NASA/NOAA Tiros N weather satellites and two USAF Defense Meteorological Satellite Program (DMSP) satellites.

The proposed system is designed so that within minutes after the satellite received a distress signal, a position fix of the distress site will be computed by a local user terminal receiving the signal relayed by satellite. This information will in turn be transmitted to the nearest rescue coordination center where search and rescue forces will be alerted and deployed. These forces will then use the same emergency transmitting signal for final location of the distress site.

The project is an international cooperative effort that will include Canada, France, and possibly the Soviet Union. The United States will provide the spacecraft, launch vehicle, and the U.S. ground stations; the Canadians will provide the space telecommunications equipment and ground station in their country; and France will provide an onboard processor and receiver.

The launch of the first search and rescue package is expected in 1982.

CHAPTER ELEVEN

MATERIALS PROCESSING IN SPACE

By Marcia S. Smith
Analyst in Aerospace and Energy Technology

Interest in the possibility of processing and manufacturing materials in the near zero gravity environment of space has existed for some time. The first space processing experiments were performed on three Apollo flights (14, 16 and 17), and continued on Skylab, the Apollo-Soyuz Test Project, and a number of sounding rocket launches in the SPAR (Space Processing Applications Rocket) program.

The concept of materials processing in space is based on the fact that in space, such processing can be accomplished without the force of gravity interfering with the procedure. Gravity is ever present on Earth, even when a vacuum chamber is used for experiments. The lack of gravity would allow production of new materials, such as metal alloys which can be made in space but not on Earth because the metals have different densities which cause them to settle into layers rather than mixing. Without gravity, the metals could combine into one homogenous material. Such metals might be better conductors than those formed on Earth.

Another promising area is electrophoresis, where molecules in a solution are separated by application of an electrical current. On Earth, such separation is limited by various factors, including gravity-induced settling of the various components of the solution and convection currents. Electrophoresis in space could have application to the preparation of pure vaccines which cannot be produced on Earth. Even small amounts of impurities in a vaccine can cause harmful side effects. Impurities can be separated from the rest of the solution using electrophoresis and removed. Although this procedure is already used on Earth, because of the settling and convection currents caused by gravity, the solution must be confined in a thin film meaning that only small quantities can be processed at a time. In space, electrophoresis could be used for large quantity on-line processing of vaccines.

I. Results From Past Experiments

There already have been several experiments concerning materials processing in space both in the United States and abroad. In the United States, experiments were conducted during the Apollo, Skylab and Apollo-Soyuz programs, and using sounding rockets (the SPAR program). The European Space Agency has conducted several sounding rocket experiments for space processing and appear very interested in continuing such experiments on the space shuttle flights in the 1980's (especially Germany). The Soviet Union has conducted a wide variety of space processing experiments, first in 1969 on Soyuz 9 (welding

experiments), and again on their manned space station series, Salyut (programs which are on-going). Space considerations do not permit detailed examination of these foreign programs.

A. APOLLO

Three space processing experiments were conducted on *Apollo 14* in 1971. First was a set of eleven experiments on composite casting which showed that material structures could be produced in space which could not be produced on Earth. Second was a heat flow and convection experiment which utilized a thin layer of oil containing aluminum flakes which demonstrated the combined effect of various forces on the kind and magnitude of fluid flow which occurs under spaceflight conditions. Third was the first electrophoresis experiment performed in space.

Further electrophoresis experiments were conducted on *Apollo 16* in 1972, and on *Apollo 17* in 1972 another heat flow and convection experiment was performed, using equipment of improved design over that on Apollo 14.

B. SKYLAB

A host of space processing experiments were performed during the three manned Skylab flights in 1973 and 1974. Two studies performed on *Skylab 2* (first manned mission) showed that welding and brazing in space is possible, while a third looked at containerless sphere formation. Eleven experiments were conducted on *Skylab 3* using a multipurpose electric furnace focusing on crystal growth, solidification, and fluid dynamics. Five crystal growth experiments, involving germanium and indium antimonide crystals, were performed. The results, which showed that more perfect crystals can be manufactured in space than on Earth, are considered important because such crystals are used in electronics. Five solidification studies were conducted, as was one experiment in fluid dynamics to determine if radioactive isotopes could be used for experiments in space to study liquid metal diffusion.

Skylab 4, the final Skylab mission, repeated seven of the experiments performed on Skylab 3. In addition, a combustion experiment was performed to determine the flammability of materials in orbital flight (it was found that ignition was the same, although burning rates were slower).

C. APOLLO-SOYUZ TEST PROJECT (ASTP)

Two electrophoresis experiments, one fluid dynamics experiments, two solidification experiments, and four crystal growth experiments were conducted during this mission. The results of the ASTP investigations were complementary to results obtained on Skylab and in general involved similar experiments on more complex materials.

D. SPACE PROCESSING APPLICATIONS ROCKETS (SPAR)

The SPAR program began in 1975 and to date there have been a total of five SPAR sounding rockets [1] launched from the White Sands

[1] Sounding rockets are small rockets which are launched vertically, continue on a suborbital flight reaching a peak altitude of about 224 kilometers (140 miles) and fall back to Earth. During descent, about 5 minutes of weightlessness is experienced during which automated experiments are performed. The total flight lasts about 15 minutes.

Missile Range in New Mexico which conduct from four to nine experiments each. SPAR flights are intended to provide basic information about space processing during the hiatus in U.S. manned space flight, for use on future flights of the space shuttle.

SPAR 1, launched on December 11, 1975, carried nine experiments. Six experiments were flown on SPAR II, launched on May 17, 1976, while SPAR III, launched on December 14, 1976, carried five experiments.

At the beginning of the SPAR program, it was decided to launch SPAR missions at the rate of two to three per year. Although all experiments on the first three SPARs functioned properly, by the time of the fourth SPAR, launched June 21, 1977, problems developed and none of the four experiments worked properly. NASA stated in testimony to Congress in September 1978 that these anomalies were the result of experiment and equipment developers taking technical risks because they were constrained to flight dates selected in the early stages of their work.[2] As a result, the fifth SPAR flight, originally scheduled for launch in the fall of 1977, was postponed for almost a year so that no experiment would be flown until its technical and scientific readiness had been verified. SPAR V was finally flown on September 11, 1978, carrying four experiments, all of which functioned correctly.

SPAR flights are expected to continue through 1980, after which a Materials Experiment Assembly (MEA) will be used on shuttle orbital flight test (OFT) missions to perform similar experiments. MEA is a self-contained experimental package with its own power source, heat rejection capacity, and processing apparatus so that only simple interfaces with the shuttle will be necessary.

II. Future Programs

The Materials Experiment Assembly mentioned above is considered only the first in a series of orbital facilities for materials processing in space. The Spacelab module, built by the European Space Agency in cooperation with the United States, is an integral part of the space shuttle system and is expected to be used for further exploration of the potential of materials processing in space. The long duration nature of the Spacelab flights (eventually up to 30 days) will enable more and better experiments over those conducted during the SPAR program.

Ultimately, if materials processing in space proves viable economically, longer duration facilities could be established either manned or in an automated mode. Proposed concepts call for space manufacturing facilities or space colonies which could include most of Earth's industry, freeing the surface of the planet for other uses. Further information on permanent space facilities, including those for space manufacturing, is presented in chapter sixteen.

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[2] Testimony of Dr. Anthony Calio, NASA Associate Administrator for Space and Terrestrial Applications, before the House Committee on Science and Technology Subcommittee on Space Science and Applications, September 26, 1978, p. 25.

III. Viability of Program

The question of whether a materials processing in space program is viable depends on a variety of factors, including whether industry will be interested in the processes or materials so produced, and whether such materials will be economical for use by the general public.

A. INDUSTRY INTEREST

The ultimate commercial viability of materials processing in space may depend on whether industry is interested either in the processes themselves or the materials manufactured in space. To date, little research appears to have been done to determine just exactly what industrial interest in this area might be, either in the United States or abroad.

One survey was conducted by Arthur M. Dula, a patent attorney, and Ann Roebke, an industrial anthropologist in 1977 which surveyed 378 companies selected from the Fortune 500 list of American industries and the Fortune 300 list of American service industries. Twenty percent of the companies responded, while another seven percent stated either that their company had no connection with the space program or had a policy against responding to questionnaires. The survey showed that although 30% of those responding were aware of and interested in communications satellites (see chapter ten) and satellite power stations (see chapter sixteen), less than a tenth of them were interested in materials processing in space such as pharmaceuticals, ultra-pure chemicals or crystal growth.[3]

Dula and Roebke found that a large majority of respondents did not consider tax treatment of space investment expenses and manufacturing profit important in determining whether their company would participate in space industrialization, although the issue of patent rights was considered extremely important. The survey results showed that a large majority of the respondents would either not consider or adversely consider space research if the government retained patent rights and granted the company only royalty free licenses. Conversely, the respondents indicated that if the government waived claims to patent rights on space-related discoveries, they would be encouraged towards participating in space industrialization.

A study performed in 1977 by Science Applications Inc. under contract to NASA on the general subject of space industrialization, including materials processing in space, found that industry was concerned about the lack of data from which to make decisions on space processing. As reported by G. Harry Stine in testimony before the House Science and Technology Committee in January 1978, industry's reaction to the idea included statements such as "The products are poorly defined at this time"; "The markets are too indefinite yet"; "The risks are very large relative to the capital outlay required"; and "The return on investment period is too long". Stine also reported, however, that nearly all of those interviewed stated that their companies would probably get involved in space processing if their competitors did.[4]

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[3] Arthur M. Dula. How Do U.S. Companies View Space Industrialization? Astronautics and Aeronautics. v. 15, April 1977 : 44–46.

[4] G. Harry Stine. In U.S. Congress. House. Committee on Science and Technology. Future Space Programs. Hearings. 95th Congress, 2d session. January 24, 25, 26, 1978. Washington, U.S. Govt. Print. Off., 1978. pp. 44–45.

In 1977, the President of Battelle Memorial Institute, Dr. Sherwood Fawcett, suggested one method for establishing more government/industry cooperation in the field of materials processing in space. Emphasizing that before industry can invest stockholder's money in a new product or procedure firm government policies on costs, liability and proprietary rights are needed. Dr. Fawcett suggested establishment of a *Space Industrialization Trust Fund* by the Federal Government.[5]

As proposed by Dr. Fawcett, the Trust Fund would sponsor research and development programs to be performed by or for a U.S. company. The company would certify that a project would lead to a new product or process which would utilize the space environment, have a potential of generating new income and public benefits through its utilization, and whose results would be used by the company if the work was successful. All information and intellectual property generated would be protected and licensed by the Government with payment of royalty to the Trust Fund up to the cost of the project plus interest. This money would then go to finance other projects. According to Fawcett, the Trust Fund concept would provide an "enormous incentive and stimulant to private industry. The public is benefited because the 'winners' pay back with interest and the 'losers' provide information which enable a future winner to be made." [6]

In the closing days of the 95th Congress, Congressman Don Fuqua, Chairman of the House Science and Technology Subcommittee on Space Science and Applications introduced a "Space Industrialization Corporation" bill (H.R. 14297), generally based on the Fawcett concept. Although the bill died with the end of the Congress, it may be reintroduced during the 96th Congress.

B. ECONOMIC VIABILITY

Assuming that industry does exhibit an interest in materials processing in space, the question of whether products so produced will be economically viable on Earth will still remain an issue. It has been reported [7] that NASA, Dow Chemical Company and Polysciences Inc. have reached an agreement on marketing latex spheres produced on the first materials processing shuttle flight in the early 1980's (these spheres are now used primarily for calibrating electron microscopes, although larger sizes which can be made in space could be used in sizing blood particles and aiding the treatment of certain lesions of the eye). The companies will reimburse NASA for the manufacturing services and market the spheres themselves to determine how such products might fare in actual market demonstration.

The National Academy of Sciences' report on the scientific and technological aspects of materials processing in space (discussed in the next section) states that the study group did not discover "any examples of economically justifiable processes for *producing* materials

[5] Dr. Sherwood Fawcett. In U.S. Congress. House. Committee on Science and Technology, Subcommittee on Space Science and Applications. Space Industrialization. Hearings. 95th Congress, 1st session, September 29, 1977. Washington, U.S. Govt. Print. Off., 1977, p. 139.
[6] Ibid.
[7] Craig Covault. Materials Processing in Space Planned. Aviation Week and Space Technology, October 31, 1977: 52–53.

in space and [the Committee] recommends that this area of material technology not be emphasized in NASA's program." [8]

By contrast, a study by Science Applications Inc., under contract to NASA on the general subject of space industrialization, including materials processing in space, showed a large market for some space-produced materials. In testimony before the House Science and Technology Committee in January 1978, G. Harry Stine, a member of the study team, revealed some of the study's conclusions.[9] While cautioning that there were many unknown variables which might change the forecasts included in the report, Mr. Stine reported that, for example, the potential market for space-produced perishable cutting tools in the year 2000 was estimated to range from $280 million to $2.8 billion. For space-produced bearing materials, he reported an estimated market of from $69 million to $690 million in the year 2000.

These attempts to quantify commercial prospects, and therefore economic viability, for materials processing in space must be considered preliminary in nature since there are so many unknowns, especially economically, for the United States between now and the year 2000.

C. NATIONAL ACADEMY OF SCIENCES REPORT

In the fall of 1978, the National Academy of Sciences' Space Applications Board released a study entitled "Materials Processing in Space," prepared under contract to NASA, which investigated materials processing in space from a science and technology viewpoint.[10]

1. Need for preflight investigations

The study emphasized that space based procedures must rely on data from previously conducted Earth-based experiments, and that without strong basic knowledge of the behavior of materials on the surface of the planet, little new will be learned in space. The question of whether NASA has provided adequate support for preflight investigations had been questioned previously by space processing researchers.[11]

While criticizing the early NASA space processing program for poorly conceived and designed experiments from which weak conclusions were drawn and, in some cases, over-publicized, the report concluded that "there is opportunity for meaningful science and technology developed from experiment in space *provided that problems proposed for investigation in space have from the outset a sound base in terrestrial science or technology and that the proposed experiments address scientific or technical problems and are not motivated primarily to take advantage of flight opportunities or capability of space facilities.*" (page 5, emphasis their's).

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[8] U.S. National Academy of Sciences. National Research Council. Space Applications Board. Materials Processing in Space. Washington, National Academy of Sciences, 1978. p. 5.

[9] Summarized in testimony to the House Science and Technology Committee by G. Harry Stine. U.S. Congress. House. Committee on Science and Technology. Future Space Programs. Hearings. 95th Congress, 2d session, January 24, 25, 26, 1978. Washington, U.S. Govt. Print. Off., 1978. pp. 3–54.

[10] Originally the Academy had planned to do two materials processing in space studies, the first on the scientific and technological aspects, the second looking at the commercial aspects of the field (proprietary rights, etc.). As of October 1978, the second study on commercial aspects had been deferred indefinitely.

[11] NASA Seeks Industry Space Processors. Aviation Week and Space Technology, January 26, 1976. p. 55.

2. Advantages of near zero gravity environment

The Academy committee looked at all the variables which exist in space and found that the only advantage to materials processing in space was the near zero gravity condition,[12] concluding that other aspects of the space environment (temperature, ambient vacuum and radiation) either had no effect on materials or their effects could be duplicated on Earth. The Committee identified four areas in which near-zero gravity environment would be useful in experimentation: the possibility of reducing or practically eliminating buoyancy-driven natural convection for substantial periods of time; the possibility of testing experimentally the basic assumptions necessary in theoretical models of systems in which complicated patterns of fluid density variation are inherent; the possibility of reducing or practically eliminating the settling of particles for substantial periods of time; and the possibility of levitating and isolating larger samples for containerless processing.

To gain a perspective on the overall viability of a materials processing in space program, the Committee chose one technology, that of growing semiconductor crystals in space for commercial use, for detailed examination. As outlined in a previous section of this chapter, a number of crystal growth experiments had been performed during the Skylab missions. Although the Committee agreed that the results obtained on Skylab showing that crystals of superior characteristics could be produced in space were valid, the Committee stated that "these results are not sufficient to permit concluding whether growth in space of crystals for commercial electronic devices is or is not viable." (page 37). The materials used in the Skylab vapor-growth experiments (gallium-seleninium (GeSe) and gallium-tellurium (GeTe)) are not expected to be used in practical electronic devices, according to the report, nor is the growth technique used expected to be used for growing those materials that do have significant practical applications. Another material, indium antimony (InSb), was also considered commercially unimportant by the Committee since it is used only in a small number of specialized infrared detectors, and the growth method (directional solidification in a closed tube) is not used for production of commercial electronic devices. Therefore the Committee concluded that it was "impossible to extrapolate the results of the InSb, GeSe, or GeTe experiments to specific materials or processes used or planned for use commercially or to predict any specific advantages of processing those materials in a low-g environment." (page 38)

3. Organizational recommendations

The Committee also issued recommendations on the organizational structure of a materials processing in space program. It suggested that the program be conducted in two phases. During Phase One, which would last for about five years, NASA should make every effort to include other agencies in the planning of appropriate experimental programs which would clearly delineate the potentials and limitations of materials processing in space, and provide NASA

[12] Some gravitational acceleration is caused by human movement within a spacecraft, movement caused by thrusters used to maintain correct orbital attitude, and the like. Therefore in an earth-orbital space station one encounters "near-zero gravity" rather than zero gravity.

with necessary experience in developing facilities of maximum value to the scientific and engineering communities.

Phase Two would see NASA as operator of the space shuttle as a national facility for materials processing, with industry and universities providing requisite funding for experiments rather than NASA. This phase would necessarily develop only if materials processing in space proved to be viable during Phase One, and in the Committee's view, if adequate funding is not supplied by the outside community, Phase Two should be discontinued.

4. General conclusions of the NAS/SAB study

The overall conclusions of the Committee were that the instances in which the low-gravity environment of space is likely to be important for materials processing in space will be few and specific, and that it found no examples of economically justifiable processes for *producing* materials in space. The Committee recommended that NASA not emphasize materials *production* (as opposed to processing) aspects of the program. The Committee also emphasized that "NASA must keep in mind that one of its proper roles is the development and operation of singular facilities in response to and not independent of the scientific and technological community."

CHAPTER TWELVE

INTERNATIONAL SPACE PROGRAMS

By Marcia S. Smith
Analyst in Aerospace and Energy Technology

The U.S. space program has been international in character since its inception. Section 205 of the National Aeronautics and Space Act of 1958, which established NASA and the U.S. civilian space program, states that "The Administration, under the foreign policy guidance of the President, may engage in a program of international cooperation in work done pursuant to this Act, and in the peaceful application of the results thereof, pursuant to agreements made by the President with the advice and consent of the Senate." (When the Act was signed by President Eisenhower, he clarified the intent of the latter part of the section by saying that it did not preclude other, less formal arrangements that would not require Senate approval.)

Congressional interest in international space programs has been evidenced recently by publications and hearings on the subject. In September 1977, the House Committee on Science and Technology published a report prepared by the Science Policy Research Division of the Congressional Research Service entitled *World-Wide Space Activities*. During the next year, that committee held hearings on international space programs as well as a panel discussion on issues concerning future international space programs. The proceedings of these events have been published by the committee.[1]

I. Types of Agreements

There are three types of agreements which can be concluded with the United States for space programs: an *Executive Agreement*, which is made on a government to government basis, with officials of each government signing the agreement; a *Memorandum of Understanding*, which is signed by the Administrator or Deputy Administrator of NASA and a comparable agency official in the other country; and *Letter Agreements* which are signed by officials within NASA's Office of International Affairs and their counterparts, or the individual scientist with whom the agreement is made. The type of agreement used depends on the scope and cost of the project.

From 1958–1977, the United States has cooperated with 73 countries in the following space activities: tracking and data acquisition,

[1] (1) World-Wide Space Activities. House Document 95–352. 95th Congress, 1st session, September 1977. Washington, U.S. Govt. Print. Off., 1977. (2) International Space Activities. Hearings. 95th Congress, 2d session, May 16, 17, 18, 1978. Washington, U.S. Govt. Print. Off., 1978. (3) Panel Discussion on International Space Activities. Hearings. 95th Congress, 2d session, June 20, 21, 1978. Washington, U.S. Govt. Print. Off., 1978. (4) International Space Activities Report. 95th Congress, 2d session. Washington, U.S. Govt. Print. Off., 1978.

sounding rockets, experiments on NASA satellites, satellites, remote sensing, ground-based programs for communication satellites, and lunar sample analysis.[2]

Satellite launches are provided to other countries on either a cooperative or reimbursable basis. In *cooperative launches*, the user country provides the satellite, while the United States provides the launch vehicle and services free of charge in return for access to scientific information from the satellite. No exchange of funds takes place. *Reimbursable launches*, on the other hand, are those for which the user country not only provides the satellite, but also pays for the launch vehicle and services. Tables 12–1 and 12–2 list all the cooperative and reimbursable launches (excluding INTELSAT).

II. U.S./U.S.S.R. Cooperation

The United States has cooperated most widely with Canada, Japan, and several European countries that belong to the European Space Agency (ESA), either under ESA's aegis or individually. Information on these programs can be found in *World-Wide Space Activities*, House Document 95–352. Although there has been less cooperation with the Soviet Union, such cooperation is significant because the U.S. and U.S.S.R. are traditionally rivals, rather than partners, in space exploration.

There have been four cooperative space agreements signed between the United States and Soviet Union: In 1962, 1965, 1972 and 1977 respectively. An analysis of the results from the first three of these agreements has been published by the House Committee on International Relations in the report "Technology Transfer and Scientific Cooperation between the United States and the Soviet Union: A Review" (see Part III, Ch. 1, "U.S.-U.S.S.R. Agreement for Cooperation in Space, pp 111–125). In summary, cooperation with the Soviet Union was slow in coming, and although it has improved during the decade of the 1970's, cooperation remains at a relatively low level.

What cooperation has occurred has primarily been in the area of information exchange, with one notable exception. In 1975, the Apollo-Soyuz Test Project took place, marking the first time spacecraft from different nations docked and conducted joint experiments in space. A Russian Soyuz, carrying two cosmonauts, docked with an American Apollo spacecraft carrying three astronauts on July 17, 1975. The ships remained docked for two days. During preparations for the mission, astronauts and cosmonauts were allowed unprecedented access to the space facilities of the other country. No American had ever been to the Russian launch center at Tyuratum, nor had one seen the interior of a Soyuz spacecraft. American space officials insisted that they have access to these areas and the Russians agreed. Information on the exact cause of death of three cosmonauts killed in a 1971 space accident was also demanded and obtained. In this respect, the United States benefited from the mission, although since Soyuz technology was found to be far

[2] Three categories of programs which NASA includes in its international program statistics are not included here: ground-based programs for meteorological and geodetic satellites, and personnel exchanges. For further information on why there are not included, and details of cooperation through the end of 1976, see World-Wide Space Activities, previously cited.

behind that of the U.S. Apollo, no new technical information of value was obtained.

Since most of the technical information concerning the U.S. civilian space program is readily available anyway, the Russians could not have learned a great deal of new technical data from their trips to the United States, either, although the cosmonauts and their support crews were allowed access to NASA and contractor facilities.

It was hoped that ASTP would open new horizons in US/USSR cooperation, and although two satellite missions have been flown by the Soviet Union on which U.S. experiments were carried (Kosmos 782 in November 1975, and Kosmos 936 in August 1977), little other cooperation has been forthcoming. Another space agreement was signed in May 1977, allowing for continued discussions of future cooperation, but no specific agreements have been made as a result of that accord. Talks continue between the two nations about future cooperation, including the possibility of sending U.S. space shuttle flights to Russian Salyut space stations, although these talks have been hampered by the recent chill in U.S./U.S.S.R. relations.

III. Results From International Cooperation

The United States' interest in international space cooperation can be divided into two categories: benefits which might accrue to the international community in general, and those which might accrue to the United States specifically. In examining the record of international programs to date, it can generally be said that success has been met in both categories, although more so in the latter.

In the first category, there is a juxtaposition in terms of attitudes of foreign nations toward the United States resulting from participation in our space program. On the one hand is the reaction of the European nations who want to have a substantial role in the post-Apollo program, but have encountered serious difficulties resulting from a lack of clear direction on the part of the United States. The recent Aerosat controversy emphasized the potential problems involved in any international agreement. The Aerosat program, for satellite assisted aeronautical navigation, involved a number of countries, including the European Space Agency (ESA). The United States originated the idea and was supposed to be the lead country. Congress approved the program, and a program office was set up within the Federal Aviation Administration. Congress subsequently withdrew its support and the American part of the project was thereupon cancelled, leaving the other nations essentially without a program.

Concern has also been expressed about the sincerity of U.S. launch assurances. The United States is major stockholder in the International Telecommunications Satellite Organization (Intelsat), whose charter states that no member country may launch a competing satellite communication system to Intelsat. The French and Germans, however, built such a satellite system, Symphonie, and requested the United States to provide launch services. To avoid conflict with Intelsat, the United States required the French and Germans to state, in writing, that the satellites were experimental only, not operational. Such a statement was provided, so the United States did launch the satellites, but the incident raised questions as to whether the United States could

be relied upon to provide satellite launches. Partially as a result of these doubts, ESA is now developing its own launch vehicle, Ariane.

On the other hand, despite these difficulties, some projects have been accomplished which might otherwise not have been, such as the German/U.S. Helios program, ESA/U.S. Spacelab, and a large number of agreements on receiving data from U.S. meteorological and earth resources satellites.

As to benefits which were to accrue to the United States specifically, the record also appears quite satisfactory. Through international cooperation, the United States was able to obtain tracking stations around the world for communicating with its spacecraft after launch. Additionally, scientific and technological benefits can be identified. Arnold Frutkin, former NASA Associate Administrator for International Affairs, noted some scientific and technical benefits in 1971 Congressional testimony:

> Scientific benefits have . . . come, for example, from wholly new data obtained from the cooperative Canadian topside sounder satellites and the Italian atmospheric density satellites, ... There are technological benefits when, in joint projects, Canadian engineers pioneered in swept-frequency ionospheric sounders and in extendible spacecraft booms, and French engineers advanced the state of the art in . . . remote sensors [and] spacecraft engineering. . . .[8]

NASA Administrator Robert Frosh, in testimony before the House Science and Technology Committee on May 18, 1978, quantified benefits to the U.S. balance of payments from international space programs:

> Since our collaborators, even in cooperative programs, often spend 10–15 percent of their funds in the U.S. for components and services, since we do conduct a large proportion of reimbursable launchings, and since independent foreign space programs look to U.S. industry for support, there is a positive contribution of space activities to the U.S. balance of payments. For the period 1965–1977, this is estimated at over two billion dollars. Some major examples are: Japanese purchases of launch vehicle components, launches, and satellites ($350 million); European Space Agency reimbursable launches ($120 million); Intelsat launches and satellites purchases (minus the U.S. contribution) ($360 million); purchases of goods and services in the remote sensing field ($50 million); and, cooperative project dollar inflow (estimated at $130 million).
>
> This dollar inflow is estimated currently at the annual rate of $175–200 million.

On balance, the international program appears to have benefited both the United States and other countries, even if the European nations seem to have suffered to some degree from U.S. uncertainties over the direction of its international programs. Some of this, of course, stems from NASA's own problems in determining the direction of the U.S. national space program now that Congress is less willing to fund expensive projects.

Many countries have benefited through access to information from U.S. communications, meteorological and earth resources satellites, from cooperative launches, and in some cases through expanding their national aerospace industries by working on NASA cooperative projects, such as Spacelab. Demand for reimbursable launches is expected to increase as more countries purchase domestic communication satellite systems. Cooperation will also become more important as the U.S. space shuttle becomes operational, especially since it will allow persons

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[8] Arnold W. Frutkin. NASA's International Space Activities. *In* U.S. Congress. Senate. Committee on Aeronautical and Space Sciences. International Cooperation in Outer Space: A Symposium. Senate Document No. 82–57. 92d Congress, 1st session, Dec. 9, 1971. p. 24.

not trained as astronauts to fly into space. It is expected that scientists not only from the United States, but those from other nations as well, will journey into space during the 1980s. For example, the first Spacelab mission is slated to include a European scientist. There appears to be a sound future for international cooperation in space as long as there is a strong U.S. national program.

TABLE 12-1

U.S. INTERNATIONAL COOPERATIVE SATELLITES

NAME	PAYLOAD CONTRIBUTOR	LAUNCH DATE	PURPOSE
Ariel I	United Kingdom	26 Apr. 1962	Ionospheric Studies
Alouette I	Canada	29 Sep. 1962	Ionospheric Studies
Ariel II	United Kingdom	27 Mar. 1964	Atmospheric Physics/ Radio Astronomy
San Marco 1	Italy	15 Dec. 1964	Atmospheric Physics
Alouette I*	Canada	29 Nov. 1965	Ionospheric Studies
French IA	France	06 Dec. 1965	Ionospheric Studies
San Marco 2	Italy	26 Apr. 1967	Atmospheric Physics
Ariel III	United Kingdom	05 May 1967	Atmospheric Physics
ESRO IIA**	ESRO	29 May 1967	Solar Astronomy and Cosmic Rays
ESRO IIB	ESRO	17 May 1968	Solar Astronomy and Cosmic Rays
ESRO IA	ESRO	03 Oct. 1968	Ionospheric Studies
ISIS I	Canada	30 Jan. 1969	Ionospheric Studies
AZUR I	Germany	08 Nov. 1969	Particles and Fields
ISIS B	Canada	31 Mar. 1971	Ionospheric Studies
San Marco C	Italy	24 Apr. 1971	Atmospheric Studies
CAS/EOLE A	France	16 Aug. 1971	Investigation of wind speeds at various altitudes
Barium Ion Cloud	Germany	20 Sep. 1971	Electric and Magnetic Fields
UK-4	United Kingdom	11 Dec. 1971	Ionospheric Studies
German A-2 (Aeros)	Germany	16 Dec. 1972	Atmospheric Physics

TABLE 12-1 (cont)

NAME	PAYLOAD CONTRIBUTOR	LAUNCH DATE	PURPOSE
San Marco C-2	Italy	18 Feb. 1974	Atmospheric Physics
ANS-A	Netherlands	30 Aug. 1974	Astronomy
UK-5/Ariel 5	United Kingdom	15 Oct. 1974	Galactic and Extra-galactic X-ray sources
Intasat+	Spain	15 Nov. 1974	Ionospheric Studies
Helios A	Germany	10 Dec. 1974	Properties and Processes in Vicinity of Sun
Helios B	Germany	15 Jan. 1976	Properties and Processes in Vicinity of Sun
CTS	Canada	17 Jan. 1976	Experimental communication satellite
ISEE-B++	ESA	22 Oct. 1977	Interaction of inter-planetary medium with Earth's environmen
IUE	United Kingdom and ESA.	26 Jan. 1978	International Ultraviolet Explorer; astronomical observations.

* Launched together with Explorer XXXI
** Launch vehicle failed
\+ Launched piggyback with ITOS-G
++ Launched with the American ISEE-A (the U.S. built ISEE-C, third in the program, was launched in 1978)

TABLE 12-2

U.S. INTERNATIONAL REIMBURSABLE LAUNCHES*

NAME	COUNTRY	LAUNCH DATE	PURPOSE
HEOS A	ESRO	05 Dec. 1968	Interplanetary Magentic Fields and Solar and Cosmic Rays
ESRO IB	ESRO	01 Oct. 1969	Ionospheric Studies
Skynet-1	United Kingdom	22 Nov, 1969	Military Communications
Skynet-2	United Kingdom	19 Aug. 1969	Military Communications
NATO A	NATO	20 Mar. 1970	Military Communications
NATO B	NATO	02 Feb. 1971	Military Communications
HEOS A-2	ESRO	31 Jan. 1972	Interplanetary Space Studies
TD-I	ESRO	12 Mar. 1972	Scientific
Anik 1 (Telesat A)	Canada	09 Nov. 1972	Domestic Communications
ESRO IV	ESRO	21 Nov. 1972	Ionospheric Studies
Anik 2 (Telesat B)	Canada	20 Apr. 1973	Domestic Communications
Skynet II A**	United Kingdom	10 Jan. 1974	Military Communications
UK-X4	United Kingdom	08 Mar. 1974	Systems Design Checks
AEROS-B	Germany	16 July 1974	Atmospheric Studies
Skynet II-B	United Kingdom	22 Nov. 1974	Military Communications
Symphonie A	France/Germany	18 Dec. 1974	Experimental Communications
Anik 3 (Telesat C)	Canada	07 May 1975	Domestic Communications
COS-B	ESA	08 Aug. 1975	Extraterrestrial Gamma Ray Studies
Symphonie B	France/Germany	26 Aug. 1975	Experimental Communications

TABLE 12-2 (cont)

NAME	COUNTRY	LAUNCH DATE	PURPOSE
NATO III-A	NATO	22 Apr. 1976	Military Communications
Palapa A	Indonesia	08 July 1976	Domestic Communications
NATO III-B	NATO	27 Jan. 1977	Military Communications
Palapa B	Indonesia	10 Mar. 1977	Domestic Communications
GEOS**	ESA	20 Apr. 1977	Scientific
GMS	Japan	14 July 1977	Meteorological
SIRIO	Italy	25 Aug. 1977	Scientific
OTS**	ESA	13 Sep. 1977	Experimental Communications
Meteosat	ESA	22 Nov. 1977	Meteorological
CS	Japan	14 Dec. 1977	Communications
JAPAN/BSE	Japan	07 Apr. 1978	Experimental Broadcasting
OTS	ESA	11 May 1978	Experimental Communications
GEOS	ESA	14 July 1978	Scientific
NATO III-C	NATO		Military Communications (scheduled for November 15, 1978)

* Does not include INTELSAT launches, which numbered 28 at the end of October 1978.

** Launch vehicle failed.

CHAPTER THIRTEEN

INTERAGENCY AND NON-NASA GOVERNMENT SPACE ACTIVITIES

By Barbara A. Luxenberg
Analyst in Aerospace and Energy Technology

I. Introduction

Since its creation in 1958, NASA has been extensively involved in interagency cooperative and liaison activities as a matter of operational practicality and legislative mandate. These activities have been both formal and informal in character and, though originally dominated by relationships with the Department of Defense (DOD), have been broadened considerably to include the many agencies of the Federal Government having research, development, and applications interests in space. Over the twenty years of U.S. involvement in space, Federal agencies have become significant users of space-derived data and space technology in fulfillment of agency missions. At the present time, many Federal agencies are involved in space activities, not as cooperative programs conducted with NASA, but rather in applying the practical benefits of space to meet agency needs.

II. History and Structure of Interagency Space Activities

The National Aeronautics and Space Act of 1958 authorized interagency cooperation in the use of services, equipment, facilities and personnel, as well as coordination of related activities among Federal agencies. Initially, as NASA developed its strengths and capabilities as an organization, it relied upon DOD for scientific and technical personnel, launch vehicles, launch facilities, and the first groups of astronauts.

However, even from 1958, NASA interacted formally and informally with other Federal agencies for the conduct of space research and utilization of space data. NASA continued the basic and applied research functions formerly conducted under its predecessor, the National Advisory Committee for Aeronautics, in cooperation with DOD, the National Science Foundation, the U.S. Weather Bureau, the National Bureau of Standards, and other agencies. As this interaction was continued and elaborated upon, several structures were set up to aid interagency interaction.

A. Civilian-Military Liaison Committee

Section 204 of the 1958 Space Act established a Civilian-Military Liaison Committee to serve as a mechanism for consultation and advice between NASA and DOD on aeronautical and space activities.

This committee served until 1965 when it was abolished by the President's Reorganization Plan No. 4 and its functions transferred to the President.

B. AERONAUTICS AND ASTRONAUTICS COORDINATING BOARD

In 1960, NASA and DOD formed the Aeronautics and Astronautics Coordinating Board. This board's function is to coordinate NASA/DOD activities, to avoid duplication, to achieve efficient utilization of available resources, to identify problems requiring solution, and to exchange information. The board serves today as the highest level formal coordinative mechanism between the two agencies. It is primarily concerned with major policy issues in space and aeronautics.

C. NASA OFFICE OF DOD AND INTERAGENCY AFFAIRS

As NASA continued its close association with DOD in its early years, NASA management perceived the need for an institutional structure within NASA to handle NASA/DOD relations. Thus, in December 1962, NASA established the Office of Defense Affairs to handle the interaction of NASA with the various branches of DOD. As NASA matured as an organization, the DOD ties remained close, but NASA developed its own in-house capabilities in terms of equipment, facilities, and personnel. Further, NASA's liaison with other agencies broadened considerably as the practical application and benefits of space technology became evident. Thus, in 1968, this office was redesignated the Office of DOD and Interagency Affairs, and its assigned functions were broadened to include all Federal agencies. The office continued its operations until the end of 1977, handling NASA's interagency agreements, technology transfer between agencies, personnel sharing, and coordination of projects. At that time, the Office of External Affairs was established within NASA, and the functions of the Office of DOD and Interagency Affairs were separated into distinct elements under the new Office.

D. NATIONAL AERONAUTICS AND SPACE COUNCIL

This council was established in the Executive Office of the President in 1958 (Section 201 of the Space Act) to advise the President on space matters, and served as NASA's official link to the executive branch. The President was chairman of the council until 1961 when a revision of the Act made the Vice-President chairman, with the other members being the Secretaries of State, Defense, and Transportation, the NASA Administrator, and the Chairman of the Atomic Energy Commission. (The 1961 revision also eliminated outside members of the council). The council was terminated in FY74 because ". . . the major policy issues of the past have been largely resolved in the national space program, and a special advisory group in the Executive Office of the President was considered no longer necessary."[1]

III. Federal Agency Civilian Space Activities

Federal agency space activities are detailed each year in the "Aeronautics and Space Report of the President" (prior to 1969, this report

[1] Aeronautics and Space Report of the President, 1973 Activities. 1974, p. 7.

was called "United States Aeronautics and Space Activities—Report to the Congress from the President"). Civilian agency space activities are briefly outlined below.

A. ARMS CONTROL AND DISARMAMENT AGENCY

The Arms Control and Disarmament Agency's (ACDA) space-related activities are oriented toward efforts to prevent arms competition in outer space. ACDA and NASA have an on-going cooperative agreement to explore the interrelationship of non-military space programs with arms control measures and their verification.

B. ATOMIC ENERGY COMMISSION

Until it was disestablished in 1975, the Atomic Energy Commission (AEC) had a long history of cooperative activities with NASA in nuclear rocket development and the development and utilization of power generators for space missions. Project Rover, initiated in 1955 and transferred to NASA in 1958, concentrated on nuclear rocket research and development. A joint AEC/NASA Space Nuclear Propulsion Office was established in 1960 to manage all nuclear rocket propulsive activities in both agencies. In 1961, the NERVA project expanded the nuclear rocket program to include rocket engine development and plans for flight testing. Activity on NERVA was terminated in 1972 for want of a defined NASA requirement for such a system. The SNAP program developed compact nuclear power generators for both space and terrestrial uses, which were used to provide power for Apollo scientific instrument packages and many deep space probes. When the AEC was abolished in 1975, its space-related activities were transferred to the new Energy Research and Development Administration (ERDA) and in 1977 to ERDA's successor the Department of Energy.

C. DEPARTMENT OF AGRICULTURE

Remote sensing of earth resources and utilization of remote sensing data in support of department missions is a major area of space-related activities in the Department of Agriculture, focussing on collection and dissemination of data from NASA's Landsat program to aid prediction of agricultural conditions and crop disasters. In 1974, NASA, Agriculture, and the National Oceanic and Atmospheric Administration began the LACIE (Large Area Crop Inventory Experiment) program to explore the value of Landsat for estimating production of wheat. The Secretary of Agriculture recently proposed an "Initiative for Aerospace Technology," which would involve cooperation between NASA, the Agency for International Development, and the Departments of Commerce and Interior, as well as Agriculture, to expand remote sensing activity in relation to agency missions. A joint planning effort based on the initiative is now underway. The Department has also established a joint NASA/Agriculture task force to document remote sensing requirements and identify areas of need for additional study.

D. DEPARTMENT OF COMMERCE

The Department of Commerce has the most extensive cooperation with NASA of any governmental agency other than DOD, and is the only civilian agency with an operational satellite program. In 1961, the Congress mandated the Department of Commerce to establish, operate and improve a system of space satellites to observe world-wide environmental conditions and to report, process, and apply resulting data. NASA would procure the spacecraft and launch them, and Commerce would operate the system.

The *National Oceanic and Atmospheric Administration* operates the environmental satellite program, which is used to keep the atmosphere, oceans, and land under constant observation. The *National Bureau of Standards* conducts many scientific activities in conjunction with NASA, provides the standards to meet space measurement problems and requirements, and furnishes basic data on the properties of matter. The *National Telecommunications and Information Administration*, established in 1978, aids planning and development of commercial communications satellite systems. The *National Weather Service* provides meteorological support for NASA launches, and uses space technology to obtain and transmit weather information speedily. The *Maritime Administration* has developed the Maritime Satellite System to advance navigation communications and capabilities. The *Bureau of the Census* has been involved in space-related activities to aid developing nations in using remote sensing to conduct demographic studies and census activities.

E. DEPARTMENT OF DEFENSE

NASA has had substantial interaction with the Department of Defense, including logistical support, sharing or loan of equipment, launch facility construction and launch support, tracking and recovery support, facility sharing, cooperative research and/or development, specific space projects, training, and personnel loans and/or transfer. The major NASA launch vehicles have usually been direct applications or derivatives of Air Force ballistic missile systems. The civilian sector in general, as well as NASA, has benefitted from DOD space activities in several ways: provision of satellite data from some DOD satellites, testing of experimental payloads in the DOD Space Test Program, and DOD laboratory research and development.

As noted above, NASA was initially very dependent upon the military for operational reasons. With the Apollo program, NASA was less dependent upon military launch vehicles and launch facilities, and the role of the military diminished. However, with the coming of the space shuttle era, NASA and DOD will share launch facilities, with NASA owning and operating the Kennedy Space Center launch facility, and the Air Force, the Vandenberg Air Force Base launch facility in California. DOD is expected to use about 40 percent of the shuttle launches, which will again mean significant liaison activities between the two agencies.

Many issues may arise out of this interaction, issues such as possible DOD operation of the shuttle program, launch priorities, conduct of national security missions, and the funding of development of advanced shuttle capabilities for military missions.

F. DEPARTMENT OF ENERGY

The Department of Energy (DOE) continues the liaison and cooperative activities in which the Atomic Energy Commission and the Energy Research and Development Administration (two of its predecessor agencies) had been involved. DOE and NASA have cooperative programs in the areas of electric and hybrid vehicles, conservation, coal extraction, solar heating and cooling, photovoltaics, wind energy, and satellite power systems. DOE is currently developing the Multi-Hundred Watt generator for future NASA missions, as well as a modular heat source designated GPHS (General Purpose Heat Source). DOE anticipates continuing its support of NASA space missions as they are authorized.

G. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

The Department of Health, Education, and Welfare (DHEW) and NASA have concluded a variety of agreements on research support, personnel, and equipment sharing. The various agencies of DHEW have also explored with NASA the possible applications of communications satellite technology to advance their educational, health, and cultural objectives. DHEW's Office of Telecommunications Policy was established in 1970 to apply telecommunications and associated technologies to the delivery of health, education, and welfare services. DHEW conducted communications experiments with the ATS satellites and the Canadian CTS satellite. The *National Institute of Health* has done a limited amount of space-related medical research.

H. DEPARTMENT OF THE INTERIOR

Since 1961, the Department of the Interior and NASA have cooperated on developing applications of aeronautical and space technologies in support of the department's missions. The two agencies cooperate on the use of property and facilities, utilization of natural resources on NASA installations, and the use of remote sensing technologies for observation and management of natural resources. In 1966, the *Earth Resources Observation Satellite Program* (EROS) was established in Interior to use remote sensing to study natural resource problems. The key facility is the data center in Sioux Falls, South Dakota, which is the repository for remote sensing data collected from Landsat, Skylab, Apollo, and Gemini spacecraft. The *U.S. Geological Survey* has participated with NASA in the lunar and planetary exploration programs.

I. DEPARTMENT OF STATE

As delineated in the National Aeronautics and Space Act, the United States has made space activities an instrument of foreign policy. Thus, the State Department is concerned with the broad spectrum of international space matters and serves to ensure consideration of foreign policy interests in development of U.S. space policy. The Department of State has the responsibility to facilitate and coordinate joint space efforts with other nations. It provides leadership and guidance for U.S. participation in the U.N. Committee on the Peaceful Uses of Outer Space and in U.N. agencies such as the International Telecommunica-

tions Union. The State Department can assist, advise and provide support on bilateral space agreements, and is also responsible for obtaining foreign cooperation in the event of space flight emergencies.

J. DEPARTMENT OF TRANSPORTATION

The Department of Transportation and NASA have cooperated in overviews of U.S. civil aviation, in studying possibilities for air traffic control satellites and ocean traffic control satellites, and in conducting experiments using NASA's ATS–1, ATS–3, and ATS–6 satellites. The *Federal Aviation Administration* and NASA cooperate in a wide range of aerospace research activities, while the *U.S. Coast Guard* provides support activities for NASA launches and has been involved in operational evaluation of Marisat and in planning for Inmarsat.

K. ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) has an extensive program with NASA to utilize proven satellite remote sensing capabilities to conduct environmental monitoring, focusing on existing environmental problems. EPA is involved in developing and evaluating remote sensing instrumentation with NASA.

L. FEDERAL COMMUNICATIONS COMMISSION

An independent regulatory agency, the Federal Communications Commission (FCC) exercises jurisdiction over space-related activities to insure that the benefits of space communications services are made as widely available as possible throughout the United States, and that the limited resources of the electromagnetic spectrum and earth orbits are allocated to space communications services as efficiently as possible. The FCC is in charge of national and international participation in, and arrangements for, aviation, marine, and weather uses of communications satellites; administration of rules and regulations concerning nongovernmental radio communications; participation in radio frequency allocation decisions; and solution of technical, operational, and policy issues related to aeronautical communications, space satellites, and radio astronomy.

M. INTERNATIONAL COMMUNICATION AGENCY

The International Communication Agency (formerly the United States Information Agency) has devoted significant resources to dissemination of information abroad about the U.S. space program. Agency coverage has focussed on the space program's human and social values, its intellectual content, and its capacity for enriching people's lives. The agency also relies on satellite communication facilities for many of its overseas radio and television transmissions.

N. NATIONAL ACADEMY OF SCIENCES

The Space Science Board of the *National Research Council* was established in 1958 to advise NASA on the conduct of the national space science effort. It develops strategies and identifies missions, as

well as responding to specific requests for advice. The Space Science Board cooperates in promoting world interest in space research and, as a major scientific advisory group, interacts with NASA on delineating U.S. space program objectives.

The Aeronautics and Space Engineering Board of the *National Academy of Engineering*, established in 1970, assesses principal aeronautical and space engineering plans and programs. The Board has studied the status of the space shuttle's main engine, and recently began a review and critique of NASA's proposed program for large space systems. In 1971, the National Academy of Engineering organized the Space Applications Board to advise NASA on the practical applications of earth satellites.

O. NATIONAL SCIENCE FOUNDATION

Prior to the establishment of NASA, the National Science Foundation (NSF) was responsible for coordination and funding of U.S. scientific participation in the International Geophysical Year. The NSF now has a role in space-related activities through its basic research programs in astronomy and atmospheric sciences. NASA and NSF have cooperated on specific research projects, in equipment sharing, in information dissemination, and in providing research support in engineering and astronomy. NSF has also worked toward inclusion of scientific experiments on NASA's space missions.

P. SMALL BUSINESS ADMINISTRATION

In the past, NASA and the Small Business Administration have had informal arrangements concerning the transfer and application of space science and technology to small businesses.

Q. SMITHSONIAN INSTITUTION

NASA and the Smithsonian Institution have an agreement on the custody and management of NASA historical space artifacts. They also have cooperative arrangements for the Smithsonian Astrophysical Observatory to conduct worldwide optical tracking activities for NASA, and for the study of lunar samples.

CHAPTER FOURTEEN

INDUSTRIAL AND UNIVERSITY SUPPORT FOR NASA

By Barbara A. Luxenberg
Analyst in Aerospace and Energy Technology

NASA, the university community, and the aerospace industry form a triangle of cooperative scientific and technical relationships and interaction which has worked toward achieving our national goals in space since the beginning of the space age and which will continue to do so in the future. This chapter briefly outlines NASA's relationships with the educational community and with the U.S. aerospace industry.

I. NASA/Industry

Under NASA's predecessor agency, the National Advisory Committee for Aeronautics (NACA), the majority of aerospace research and development was conducted in-house at the NACA facilities. With the formation of the National Aeronautics and Space Administration (NASA) in 1958, came plans for a vast new space program of manned space flight, lunar probes, scientific satellites, planetary probes, weather satellites, aeronautical research, and development of larger launch vehicles. To carry out such an ambitious program, NASA needed capabilities it did not have. In addition to expanding its internal capabilities, NASA turned to industry for the support it needed. From its inception, NASA, unlike NACA, conducted the majority of its work through contracts with industry, though it also developed in-house capabilities.

The challenge of the Apollo program is seen to be the major stimulus to development of the NASA aerospace industry resource in the 1960's. Through this program a single agency, NASA, was charged with meeting a specific objective, going to the Moon, on a specified budget and within a given schedule. NASA's funding during the 1960's made possible rapid growth of space technology and hardware capability both within the agency and throughout the industry. During its peak funding years in the mid-1960's, about 90 percent of the NASA budget was spent in the private sector. Though this percentage has dropped at times (especially in the early 1970's), for FY 77 about 90 percent of NASA's procurement dollars resulted either directly or indirectly in contracts with industry.

To serve as liaison between NASA and industry, NASA established the Office of Industry Affairs. Organizationally, this office has been located in a number of different places in the NASA structure, and has included various functions. Until recently, the Office of Industry Affairs included technology utilization, that is, promotion of utilization of the secondary benefits of space technology. At one time, the Office of Industry Affairs had responsibility for industrial procure-

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ment and contracting as well, although for the most part, these functions have been the responsibility of a separate Office of Procurement and Contracting.

Contracting authority was granted to NASA by the National Aeronautics and Space Act under the authority of the Armed Services Procurement Act of 1947. NASA is enabled to use competitive bidding or negotiation in making contractor selections, or can award contracts on a sole source basis. In FY 77, 73% of NASA's direct awards to industry were from competitive negotiations, and 27% were noncompetitive.

NASA, of necessity, has developed a much larger and more sophisticated contracting organization than had NACA. To a large extent, NASA followed the Department of Defense's (DOD) contracting procedures and methods because basically DOD was working with the same aerospace industries. To facilitate handling of contractual problems, NASA established the Board of Contract Appeals and the Contract Adjustment Board.

Because precise design characteristics are often not available for hardware needed for operational space programs, and because there are significant unknowns in space technology, NASA has found flexible, "cost-plus" contracts to be of greater utility than fixed price contracts. NASA did devise incentives for cost savings under such contracts in order to penalize poor performance and reward high performance. In FY77, in contract awards over $10,000, 69% had incentive provisions, only 13% were straight cost plus fixed fee, and only 15% were firm fixed price.

Because space contracts can be worth significant amounts of money, NASA has attempted to ensure that funds to industry are given the widest possible distribution geographically. For all research and development contracts over $500,000 and subcontracts over $100,000, NASA requires contractors to solicit proposals from the widest geographical area consistent with efficient performance and maintenance of low costs and high effectiveness.

NASA has created opportunities for small businesses to participate in its procurement program using a number of different mechanisms: it maintains communication with small businesses to advise them of opportunities for submitting proposals; it sets aside certain competitions for small businesses only; it has small business specialists on its staff; and it requires prime contractors to seek and report on small business contracting. In FY77, small businesses received 9% of NASA's direct awards to industry and subcontract awards from 87 of NASA's prime contractors. The total of these two categories is estimated to be 18% or $496 million of NASA FY77 awards to industry.

To further the NASA/industry relationship, NASA has established a number of internal policies and mechanisms to facilitate interaction. NASA has opened many communication links with the aerospace industry to inform industry of its program needs. NASA makes available government research and test facilities to industry as well as the services of its technical and management staffs. The Inventions and Contributions Board, set up at headquarters in 1968, has the authority to waive NASA's patent rights to discoveries made by industry under NASA contract. The Board also surveys the progress that NASA and

industry are making in the commercial application of such inventions and discoveries.

Employment in the aerospace industries was at its peak in 1968 but between 1968 and 1971, it dropped from about 1.5 million to about 900,000. The most current figures for 1978 indicate that employment in the aerospace industries is just under 960,000. Cyclical employment and space program funding has, of course, created problems for the industry and some people have seen this as a force which will diminish the strength of the U.S. aerospace industry. At hearings in 1973 before the Senate Committee on Aeronautical and Space Sciences, industry witnesses noted the success of NASA/industry relations in achieving the goals of the Apollo program and suggested that their interaction has established a major national resource which was, due in part to NASA budget constraints and waning popular support for the space program, not being used optimally and in danger of being disbanded. Many witnesses suggested that NASA activity be sustained at levels which would enable it to continue its extensive interaction with the aerospace industry to maintain the industry as a national resource which could be used optimally as an element in U.S. policy to meet national and global needs.

Today the emphasis in the U.S. space program is on the practical application of existing space technology, either directly or indirectly, to benefit all. The utilization of available technology, rather than major new developmental initiatives, is called for in the U.S. civilian space policy as enunciated in October 1978 by President Carter. In hearings before the House Committee on Science and Technology in the spring of 1978, witnesses called for increased industry/government partnership in space activities to keep the United States in the forefront of space technology as international capabilities increase. Many people perceive that the NASA/aerospace industry resources and capabilities can be applied to national needs through direct contribution to the nation's needs, through ancillary benefits or spin-offs from space-oriented efforts, and application of aerospace management and technical know-how to solve non-space problems.

II. NASA/Universities

At NASA's inception, there was concern about the wide gap between national ambitions in space and national competence to fulfill those ambitions. The importance of developing that competence in institutions of higher education was stressed by Dr. James A. Van Allen:

> Only if Universities are full-fledged partners in the national space effort can we develop the broadgage, long-term competence which the public and the Congress so ardently expect. . . .
>
> We do not need gimmicks. But we do need facilities. We need research support, we need to establish a favorable competitive situation for the maintenance of a professional faculty and staff, and we need student fellowships. The cost is a minuscule fraction of the national space budget. I believe that the results will be strikingly important.[1]

To achieve its mission, NASA policy was to foster the scientific and engineering resources available at institutions of higher education and to bring them to bear on the Nation's aerospace program. Since

[1] James A. Van Allen. Education's Role in Space. Aviation Week and Space Technology, Oct. 16, 1961 :21.

1959, NASA has funded project research at colleges and universities throughout the United States. In so doing, NASA was following the directives of the National Aeronautics and Space Act of 1958 to make the ". . . most effective utilization of the scientific and engineering resources of the United States. . . ." The objective has been to bring the scientific, engineering, and social research competence available in the university environment to bear on aerospace problems and on the broader implications of NASA's technical and scientific programs without diminishing the strengths of that resource. A prime objective was to strengthen university educational and research capabilities through interaction with NASA.

Under NACA, there had been a Research Coordination Division which handled NACA/university interaction. This function continued in NASA, and the original NASA office was called the Office of University Research. There have been a number of name changes since that time, and the office is currently known as the University Affairs Office. Its functions have evolved over the years but there are certain key elements which have remained constant. This office serves as the focal point for NASA's interaction with educational institutions. It administers the university program. It functions in an oversight capacity for NASA centers' interaction with universities and manages NASA grants and contracts with universities. It also helps define NASA/university policy. One of the functions of the office is to provide information on NASA's university program and it prepares three annual reports to accomplish this task: *NASA's University Program—Active Grants and Research Contracts; Summary University Program Information;* and *NASA Obligations to Educational Institutions.*

Though NASA did not intend to draw researchers away from the universities or from their educational roles, educational institutions were a major source of manpower for NASA as it started on the Apollo program in the early 1960's. NASA realized that while the government, industry, and research foundations all used the trained scientific and engineering manpower resource, only the universities could replenish that resource. NASA was sensitive to the fact that it was a prime user of university-trained talent and believed that it should bear its fair share of the cost of replacing that manpower. To strengthen the university resource, to encourage the training of scientists and engineers, and to support university involvement in space research, NASA started its Sustaining University Program in 1962.

The Sustaining University Program (1962–1970) was designed to increase university participation in space science and technology and to complement the expanded research activity of NASA. The program included graduate training grants to increase the supply of professional technical personnel in space-related science and technology; facilities grants for construction of much-needed laboratory facilities for space research; and special-purpose grants to academic institutions to encourage creative investigations in scientific disciplines. NASA was subject to some criticism for being actively involved in university affairs through this program which some people believed to go beyond the scope of NASA's mission of research and space flight activities. NASA's position, during the 1960's, was that such a program was necessary at that time, to ensure the availability of trained scientific and technical manpower.

Today NASA relies on the university scientific community as a primary scientific resource and encourages university scientists to become principal investigators in developing experiments to be flown in space. In addition to the experimental programs, NASA has had a broad range of grants to promote space-related research at educational institutions.

Along with the formalized ties to the university community, NASA has encouraged informal exchange and has set up numerous summer institutes, and fellowship programs. NASA employees have been sent to universities for upgrading and updating their training, as well as having employees conduct post-doctoral and adjunct teaching. NASA has encouraged university faculty to serve industry, their communities and the U.S. Government for the advancement of space research.

Funding for NASA's university programs has gone from $5 million in FY60 to $124.9 million in FY77 with an estimated $133 million in FY78 and in FY79. In FY60, NASA university program funds were less than one percent of NASA appropriations; in FY77, they amounted to 3.27 percent of NASA's appropriations, a level they have maintained during the 1970's.

With this funding, NASA has supported research in over four hundred educational institutions in all fifty States, the District of Columbia, and two territories. It has also supported work in forty educational institutions in nineteen foreign countries. This support has been carried out in the past though grants and contracts through the Federal Grant and Cooperative Agreement Act of 1977 (PL 95–224) may impact on the format of NASA's support for university research.

The Federal Grant and Cooperative Agreement Act is an attempt to distinguish between Federal grant and cooperative agreement relationships (assistance) and Federal procurement relationships (contracts), and it stipulates appropriate methods of transactions in each instance. At this time it is not clear how this will impact on NASA university programs. Agency guidelines are currently being developed, and NASA is consulting with the Office of Management and the Budget on how NASA can apply the principles of P.L. 95–224 to its support for the university program. NASA's position has been that it does not provide assistance to universities; rather, NASA is buying research for NASA's direct use. Thus, under the terms of the Act, NASA would apparently need to conduct all its university relationships as procurement of services through contracting procedures. This would entail developing an efficient and workable procedure for contracting with universities for research.

As the method of NASA's implementation of the requirements of this new law is uncertain at this time, it may be that NASA will still be conducting some of its university relationships as assistance relationships. Whatever final arrangements are instituted, they would not change the content of NASA's university program, but only the procedures by which that program is conducted.

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CHAPTER FIFTEEN

SPACE PROGRAM BENEFITS

To enable Congress and the public to assess the costs and benefits of the space program to the country as a whole, attempts have been made to measure the results from the space program in terms of economic and/or technological benefits, which can then be weighed against the annual expenditures for space. Three approaches to this quantification process are: studying the impact of funding for space on the U.S. economy; utilization of space technology in other sectors of the economy (technology transfer); and spinoffs (individual devices which can trace their origin to space technology).

I. Economic Impact of NASA Spending

(BY MARCIA S. SMITH, ANALYST IN AEROSPACE AND ENERGY TECHNOLOGY)

One method of attempting to quantify benefits to the Nation from the space program is through studies of economic benefits resulting from pursuit of a space program, as distinct from other technological programs. In the past several years, four such studies have been performed: one by Rockwell International on the effects of the space shuttle program on the State of California's employment situation (California is home to many space industries, including Rockwell International); another by the Midwest Research Institute focusing on an econometric analysis of the effect on the GNP of technological progress over the period 1949–1970; a third by Chase Econometrics Associates which investigated the total macroeconomic impact of NASA expenditures on the U.S. economy; and finally, a report by Mathematica, Inc. which estimated the national benefits from four specific secondary applications of technological advances accelerated by space research and development.[1]

Each of these studies will be summarized below, although it should be noted that no attempt is made here to assess critically the studies in terms of methodology and resulting conclusions. Only the Chase Econometrics Study has been so assessed (by the General Accounting Office) and results of that critique are presented.

A. ROCKWELL INTERNATIONAL STUDY

In December 1974, Rockwell International released a report entitled "Impact of the Space Shuttle Program on the California Economy." Using the University of California at Los Angeles (UCLA) econo-

[1] Two studies have also been performed on the impact via NASA's Technology Utilization Program. The summary conclusions of these studies are discussed in section II of this chapter.

metric model of the State of California's economy, the study focused on the impact of NASA's space shuttle program (for which Rockwell International is the prime contractor) on statewide employment, with consideration also given to the program's effects on gross State product, personal income, and tax receipts.

The study concluded that the shuttle program would create about 266,000 man-years of employment in California, which translates into over 49,000 jobs. Forty-two percent of that increase in employment would be in the aerospace industry, while the remaining 58 percent would be distributed among the non-aerospace sectors of the economy, particularly services (45,300 man-years), trade (37,000 man-years), and government (31,900 man-years).

The study also found that an employment multiplier of 2.8 could be attributed to the shuttle program, that is, those people hired to work on the shuttle program in California would respend a large fraction of their income within the State, creating income for those providing the purchased goods and services. The employment multiplier means that 1.8 additional jobs are created for each directly related shuttle job. The Rockwell study found that direct shuttle employment would be 95,300 man-years, while the increase in total employment (see table 15–1) would be 266,000: 266,000 divided by 95,300 equals 2.8.

TABLE 15-1

CALIFORNIA EMPLOYMENT GENERATED BY THE SPACE SHUTTLE PROGRAM
(in Man-Years)

Sector of the Economy	Orbiter*	Total
Manufacturing	106.000	125,000
Shuttle	(81,700)	(95,300)
Other aerospace	(14,300)	(16,900)
Durables (non-aerospace)	(6,500)	(8,400)
Nondurables	(3,500)	(4,400)
Contract construction	8,000	9,800
Mining and agriculture	0	0
Transportation, communications, and utilities	5,000	6,500
Trade	27,000	37,000
Finance, insurance and real estate	8,000	10,500
Services	41,000	45,300
Government	28,000	31,900
Federal	(10,500)	(11,400)
State and local	(17,500)	(20,500)
TOTAL	223,000	266,000

* The economic effects of the space shuttle integration contract are included with those of the orbiter.

Source: Rockwell International. Space Division. Impact of the Space Shuttle Program on the California Economy. Los Angeles, California, Rockwell International, December 1974. SD74-SH-0334, page 9.

The study also concluded that development of the space shuttle would cause the gross State product to increase by $5.6 billion; personal income to increase by about $3.7 billion; California State and local tax revenues to increase by $560 million; and that the expansion of economic activity in the State would generate an additional $1 billion in Federal tax revenues.

The author of the study, Ted Gibson, senior economist in Rockwell's government affairs division, noted that the assumptions used in the study tended to make the calculations conservative, and understate the impact on the State's economy. For example, it was assumed that no subcontracting activity or material purchases would occur within

California in connection with the shuttle's external tanks; only California-based subcontractor work was assumed for the solid rocket booster, so estimates of material purchased in California for these boosters were not included; and the values of all subcontracts for the orbiter and main engines expected to awarded out of State were excluded.[2]

B. THE MIDWEST RESEARCH INTITUTE STUDY

In 1971, the Midwest Research Institute (MRI) released a study it prepared under contract to NASA entitled "Economic Impact of Stimulated Technological Activity." The overall study effort concerned the relationships between technological progress and economic development, focusing on the ways in which NASA research and development aids in the accumulation and commercial application of new or improved scientific and technological knowledge. The report was divided into three parts: (1) "Overall Economic Impact of Technological Progress: Its Measurement" which measured the economic effect of technological progress; (2) "Case Study: Technological Progress and Commercialization of Communications Satellites" which illustrated the process whereby technology is developed and commercially applied; and (3) "Case Study: Knowledge Additions and Earth Links From Space Crew Systems" which showed that mission-oriented R&D generates new or improved knowledge in many fields that is added to the Nation's knowledge bank for withdrawal when needed. (In addition, a summary volume and a bibliography were published.)

The MRI study concluded that "technology added to the Nation's production recipe after 1949 accounted for 40 percent of the real increase in private, non-farm output during the period [1949–1968]" (p. 8). Assuming NASA's R&D expenditures to have the same pay-off as the average R&D expenditure, MRI found that:

> The $25 billion, in 1958 dollars spent on civilian space R&D during the 1959–1969 period has returned $52 billion through 1970 and will continue to provide pay-off through 1987, at which time the total pay-off will have been $181 billion. The discounted rate of return for this investment will have been 33%. (p. 10)

MRI further stated that since NASA allocates its dollars to the more technologically advanced segments of industry, there may be greater than average returns from NASA expenditures on research and development.

C. THE CHASE ECONOMETRICS REPORT

In April 1976, Chase Econometrics Associates of Bala Cynwyd, Pennsylvania released the final version of "Economic Impact of NASA R&D Spending" (NASA CR 144351), prepared under contract to NASA. The study investigated both the long and short term effects of R&D spending on the economy, particularly NASA R&D spending. Focusing on the demand and supply effects of increased R&D spending, the study found that the demand effects were primarily short-run in nature and have had consequences similar to that of other types of government spending, while supply effects are long-run in nature and have had consequences very dissimilar to that of general types of government spending.

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[2] Rockwell International, Space Division. Impact of the Space Shutle on the California Economy. Los Angeles, California, December 1974. SD 74–SH–0334. p. 7.

In the first part of the study, which measured the short-run economic impact of alternative levels of NASA expenditures for 1975, the Chase study concluded that a shift toward higher NASA spending within the framework of a constant level of total Federal expenditures would increase output and employment, and would probably reduce the inflationary pressures existing in the economy; therefore Chase concluded that NASA spending is more stabilizing in a recovery period than general government spending.

In the second part of the study, Chase attempted to measure the impact of NASA R&D spending, and other determinants of technological progress, on the rate of growth in productivity of the U.S. economy. Chase found that the historical rate of return from NASA R&D spending is 43%.

In the final part of the study, Chase simulated the relationship between NASA R&D spending and technological progress to measure immediate, intermediate, and long-run economic impacts of increased NASA R&D spending over a sustained period. The Chase findings showed that an increase in NASA spending of $1 billion (1958 dollars) for the 1975–1984 period would have the following effects:

(1) Constant-dollar GNP would be $23 billion higher by 1984, a 2% increase over the "baseline," or no-additional-expenditure projections.

(2) The rate of increase in the consumer price index would be reduced to the extent that by 1984 it would be a full 2% lower than indicated in the baseline projection.

(3) The unemployment rate would be reduced by 0.4% by 1984, and the size of the labor force would be increased through greater job opportunities so that the total number of jobs would increase by an additional 0.8 million.

(4) By 1984 productivity in the private non-farm sector would be 2.0% higher than indicated in the baseline projections.

Other simulations, of $100–$500 million increases, show proportional results.[3]

On October 18, 1977, the General Accounting Office (GAO) released a critique of the Chase study, prepared at the request of Senator William Proxmire, entitled "NASA Report May Overstate the Economic Benefits of Research and Development Spending" (B–164912). The GAO stated that the Chase study did not prove "convincingly" that the benefits were as large as stated in that report. GAO considered the Chase conclusion questionable from three points of view: (a) even if the Chase results were accepted as accurate, they do not provide the type of information needed to determine whether NASA spending should increase or decrease; (b) even if the Chase approach is accepted, the techniques used had certain shortcomings such that "plausible and seemingly minor changes in the study's assumptions lead to major changes in the results"; and (c) that "Basically, the results depend upon statistical correlation between NASA research and development spending and changes in the measure of gross productivity in the U.S. economy. No information on specific NASA projects or on the adoption of new techniques by private business is used in the study. Because of problems in measuring total productivity in the economy and because other possible causes of technological progress

[3] Chase Econometrics Associates, Inc. The Economic Impact of NASA R&D Spending—Executive Summary, Final Report. [n.p.], April 1976. NASA CR 144351. p. ii.

were ignored, the correlations may not indicate a true cause-and-effect relationship." [4]

GAO also commented, however, that "Although the methodology of a particular study may be questioned, the importance of evaluating NASA's programs is undiminished. NASA has clearly been an important source of technological progress in recent years" (p. D2) and that although the Chase study is not a definitive budget justification, "it is a worthwhile exploratory approach to a difficult problem in economics" (p. 12).

Both NASA and Chase Econometrics were afforded the opportunity to comment on GAO's findings, and both generally agreed with the GAO comments. NASA replied that the "GAO analysis is well done and does not take issue with the results" and that the differences between the Chase study and the GAO analysis is "based on the art of interpreting the statistical results." For example, where Chase chose a regression equation which, when analyzed, showed a 43 percent rate of return to NASA R&D funding in which the "NASA R&D" variable was statistically significant, the GAO chose an equation that included the greatest number of explanatory variables at the expense of the statistical reliability of the "NASA R&D" variable. GAO also used a longer time span which included a period without NASA spending (1956–1974), while Chase chose a period which had heavy NASA funding (1960–1974). NASA stated that "interpreting the regression equation that the GAO prefers (which was one of the many equations Chase had analysed and rejected) yields a 28 percent rate of return to NASA R&D" as opposed to the 43 percent shown in the Chase study. "This result is still well within a range of economic returns that can be considered very good investment of government R&D funds." [5]

Michael Evans, who performed the study for Chase, responded that he found the GAO critique "fair to all sides concerned." [6]

D. MATHEMATICA, INC. STUDY

"Quantifying the Benefits to the National Economy from Secondary Applications of NASA Technology," a study prepared by Mathematica, Inc. under contract to NASA, was released on June 30, 1975. This report sought to develop preliminary estimates of the economic benefits to the U.S. economy from secondary applications of NASA technology, where "technology" was defined as "the body of knowledge concerning how society's resources can be combined to yield economic goods and services," NASA technology, then, is NASA's contribution to this body of technical knowledge.

Mathematica chose four specific examples of secondary application of NASA technology: cryogenic multilayer insulation materials, integrated circuits, gas turbines in electric power generation, and development of the NASTRAN (*NASA Str*uctural *An*alysis) computer software package.

The conclusions of the study were that:

(*a*) Operational methods can be developed for estimating the secondary benefits of mission oriented R&D;

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[4] U.S. General Accounting Office. NASA May Overstate the Economic Benefits of Research and Development Spending. Report to the Congress by the Comptroller General of the United States. Washington, General Accounting Office, October 18, 1977. B–164912.

[5] Ibid. Appendix III.

[6] Ibid. Appendix IV.

(*b*) Secondary benefits attributable to NASA's R&D programs may be impressively large. For example, the $7,000 million total for the four cases studied [see Table 15–2] is more than twice NASA's present yearly budget.

(*c*) Because secondary benefits may indeed be significant, public decisions concerning the allocation of resources to research and development programs should, where possible, consider such benefits.[7]

In summarizing its conclusions, Mathematica cautioned that although the results were "arrived at through careful and rigorous techniques," they are "sensitive to data uncertainties and analytical simplifications."

TABLE 15-2

MATHEMATICA STUDY: RESULTS OF BENEFITS ESTIMATION

Technology	Interval of Benefits Estimation	Estimated Probable NASA Acceleration (Years)	Probable Benefits Attributable to NASA (millions)
Gas Turbines	1969 - 1982	1.0	$ 111
Cryogenics	1960 - 1983	5.0	$1,054
Integrated Circuits	1963 - 1982	2.0	$5,080
NASTRAN	1971 - 1984	4.0	$ 701
TOTAL			$6,946

Source: Mathematica, Inc. Quantifying the Benefits to the National Economy from Secondary Applications of NASA Technology: Executive Summary. Princeton, New Jersey, Mathematica, Inc., June 30, 1975. NASA Contract NASW-2734. page 9.

[7] Mathematica, Inc. Quantifying the Benefits to the National Economy from Secondary Applications of NASA Technology, Princeton, New Jersey, Mathematica, Inc., June 30, 1975. p. 10.

II. Technology Transfer and Utilization

(BY LANI H. RALEIGH AND BARBARA A. LUXENBERG, ANALYSTS IN AEROSAPCE AND ENERGY TECHNOLOGY)

Recognizing the potential benefits of space technology, the Congress included a provision in the National Aeronautics and Space Act of 1958 which requires that NASA "shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." In 1963 the agency established the Technology Utilization Program, designed to accelerate and broaden the transfer of aerospace technology to public and private sectors of the economy. NASA employs a variety of mechanisms to meet the objectives of this program.

NASA publishes a series of publications to advise potential users of available NASA-developed information and technologies. Under the provisions of the National Aeronautics and Space Act, NASA contractors are required to furnish written reports "containing full and complete technical information concerning any invention, discovery, improvement, or innovation" which may be developed in the course of work for NASA. These reports provide input to NASA's principal technology utilization publication, "Tech Briefs". Issued quarterly, "Tech Briefs" contain information on newly-developed processes, advances in basic and applied research, innovative concepts, improvements in shop and laboratory techniques, and new sources of technical data and computer programs.

Another technology publication deals with NASA-patented inventions available for licensing, now numbering more than 3,500. A summary of all available inventions, updated semi-annually, is contained in the "NASA Patent Abstracts Bibliography".

NASA also publishes "Computer Program Abstracts" an announcement bulletin which gives notice of government-developed computer programs available for adaptation to industrial use.

In addition to these regular publications, NASA publishes a variety of special publications—reports, technical handbooks, data compilations—to acquaint the non-aerospace user with NASA advances in technology. Examples include new developments in welding and soldering, lubricants and lubricating techniques, human factors engineering sterilization and decontamination.

To promote technology transfer within the Nation's industrial complex, NASA operates a network of Industrial Applications Centers (IACs) whose function is to provide information retrieval services and technical assistance to industrial clients. Staffed by scientists, engineers, and computer retrieval specialists experienced in industry liaison, the IACs seek to broaden and expedite technology transfer by helping industry find and apply information pertinent to a company's projects or problems and to thus avoid duplication of research already accomplished and thoroughly documented in the data bank.

Through the IACs, industry has access to over ten million documents, the world's largest repository of technical data. Nearly 1.5 million of these documents are NASA reports. In addition, the data bank includes the continually updated contents of 15,000 scientific and technical journals, as well as thousands of published and unpublished re-

ports compiled by industrial researchers and by government agencies other than NASA.

A supplement to the IAC network is the State Technology Applications Center (STAC) program. Its goal is to facilitate technology transfer to State and local governments, as well as to private industry, by working with existing State mechanisms for providing technical assistance. The STACS perform services similar to those of the IACs, but where the IAC operates on a regional basis, the STAC works within an individual State, focusing on areas not normally served by the IACs.

A related service to industry is provided by NASA's Computer Software Management and Information Center (COSMIC) at the University of Georgia. COSMIC collects, screens and stores computer programs developed by NASA and other government agencies. Adaptable to secondary use by industry, government or other organizations, these programs perform such tasks as structural analysis, electronic circuit design, chemical analysis, design of fluid systems, determination of building energy requirements and a variety of other functions.

Yet another aspect of NASA's Technology Utilization Program includes applications engineering, the use of NASA expertise to redesign or reengineer aerospace technology for the solution of problems specified by Federal agencies or other public sector institutions. Applications engineering projects originate in one of three ways. A government agency may ask NASA directly for assistance in the solution of a problem. Another way is for a technician at one of NASA's field centers to perceive the possible solution of a public sector problem by adapting existing NASA technology to meet that need. A solution is proposed and reviewed for technical feasibility and cost. If the project is approved, NASA and the user agency may begin a cost-sharing effort which includes design, development, evaluation, and field testing of prototype hardware. A third method of project origination involves Application Teams consisting of several NASA scientists and engineers who represent different disciplines located at research institutes and universities. The teams contact public sector agencies, medical institutions and trade or professional organizations to learn what significant problems might be susceptible to solution through application of NASA technology. Having identified a problem, they contact appropriate individuals at NASA field centers to determine what existing technologies might be applied to the problem. Matching technology to need, the teams often conduct technology demonstrations as a first step toward bringing about commercialization or institutional acceptance of the technology transfer. The six application teams concentrate their efforts in the fields of medicine, public safety, transportation, and increased industrial productivity.

Though NASA employs a number of different means to enhance the transfer of space-derived data and technology to the public and private sectors, the importance of assuring the largest possible utilization of space program benefits has been of increasing concern both within and outside of NASA. In 1977, the Congress requested NASA to conduct a cost-benefit study of its Technology Utilization Program. The summary results of the study, as prepared for NASA by the Denver Research Institute, assert that the program benefit-to-cost ratio is

at least 6:1, i.e., for every dollar invested in NASA's Technology Utilization Program, there is a net economic return of six dollars.[8] NASA hopes to apply the results of this study to a better understanding of the technology transfer process, thus enabling improvement of the process and a resultant increase in benefits to be derived from the public and private investment in it.

With advances in Earth observation technology and the imminence of the space transportation system era, extraordinary opportunities for the utilization of space-related technology and data will occur in the next decade. In his newly enunciated U.S. civilian space policy, President Carter emphasized increasing the practical and economic benefits for resources expended for these activities. In the past few years, there has been closer examination of NASA's efforts to meet user needs and to transfer technology to potential users. As the space shuttle becomes operational, this scrutiny will undoubtedly continue and additional mechanisms will be sought to enhance space technology transfer and utilization.

III. Indirect Benefits From Space—Secondary Benefits of Space Technology

(BY LANI H. RALEIGH, ANALYST IN AEROSPACE AND ENERGY TECHNOLOGY)

Space exploration has made major contributions to mankind's earthly technological advancement. Technology is a vastly important commodity of this century. It generates new conveniences and improved necessities for a better quality of life; it is a tool for increased productivity and therefore contributes to the Nation's prosperity; it is an instrument of international prestige and it affords a means of helping the lesser developed nations.

For maximum effectiveness, technology needs momentum and direction. NASA's mission, to further the knowledge of our universe, plays a vital role in providing stimulus and focus. The enormity of sending a spacecraft to another planet requires a technological thrust of prime magnitude. The extraordinary demands of programs such as Viking, Apollo, the space shuttle, and a variety of aeronautical research projects have thus spurred an explosive innovative research and development effort that reaches into virtually every scientific and technological discipline, creating a storehouse of new knowledge.

This new knowledge can provide both direct and indirect benefits to mankind. Direct benefits include communication via satellite, imagery from Earth resources satellites, space-derived meteorological data, etc. Indirect, or secondary benefits of space technology, include numerous technological innovations which had their origin in the space program but may be applied to many other areas, such as medi-

[8] Two studies were prepared for NASA on the Technology Utilization Program: "NASA Tech Brief Program: Cost Benefit Evaluation" by the Denver Research Institute, University of Denver (NASA Contract NASW–2892, May 1977), and "A Cost-Benefit Analysis of Selected Technology Utilization Programs" by Mathtech, Inc. (NASA Contract NASW–2731, November 7, 1977). Since the two studies employed different methods for estimating benefits generated by the NASA Technology Utilization Program, they produced different results. The Denver Research Institute prepared a summary of the reports entitled "NASA Technology Utilization Program: A Summary of Cost Benefit Studies" which was published in December 1977 (NASA Contract NASW–3021). This citation is from page 27 of the summary volume.

cine, industry, safety, transportation, and energy. Technical devices resulting from space research which are used in these areas include arterial pulsewave transducers for detecting arteriosclerosis, voice-controlled wheelchairs, the NASTRAN computer program which enables engineers to study performance and structural behavior of a number of different designs before settling on a final configuration and proceeding with construction, improved firefighting equipment, advancements in solar cell technology, and heat pipes which safely dissipate the heat of the Alaska pipeline without environmental damage to the permafrost.

CHAPTER SIXTEEN

SELECTED FUTURE SPACE PROGRAMS

I. Outlook for the Future of the U.S. Space Program

(BY MARCIA S. SMITH, ANALYST IN AEROSPACE AND ENERGY TECHNOLOGY)

Other chapters of this study detail what has been accomplished in the U.S. space program in the past 20 years; the question can now be raised as to what the future may hold in store. The answer lies primarily in what level of funding Congress and the Administration choose to provide for space program endeavors, which in turn depends at least in part on public opinion and support of space goals.

Public opinion has been a major driving force in the space program in the past. When the public felt threatened by Russian successes in space flight, for example after the first Sputnik launch, there was substantial public support for U.S. space efforts in the hope of denying the Russians an overwhelming lead in space technology. The "Moon race" developed from this concern. Once Americans landed on the Moon in 1969, and it appeared that the Russians were not even close to paralleling that feat, public support for the space program waned.

It would be too simplistic to suggest that merely our accomplishment of President Kennedy's goal of landing men on the Moon was the single cause for diminished public support for space. There were a number of reasons, including rising inflation, caused in part by the Vietnam War, and increased social unrest. As we moved further out into space, some elements of society became more concerned about the vulnerability of life on the planet. Critics began to decry the use of Federal monies for space exploration when so many problems required solution on the planet itself, contending that space would always be available for exploration and could therefore wait until more crucial problems were solved.

NASA's funding peaked at $5.25 billion in fiscal year (FY) 1965 and steadily declined to a low point of $3.02 billion in FY 1974 where it has risen only to a FY 1979 level of $4.35 billion, which includes increases to counteract inflation. It appears likely that the budget level will remain at a relatively constant level (other than for inflation) for the foreseeable future unless some event similar to Sputnik once again propels the United States into another "moon race" type of effort.

The following chapter describes some possible future space programs which are currently being discussed. These represent major new program initiatives, as opposed to continuing programs which have already begun. For example, future exploration of Mars by unmanned probes is discussed in chapter nine under "Viking," rather than here. The value of these programs will have to be determined both indi-

vidually and in relation to the overall needs of the nation; therefore no attempt is made here to prioritize them. A broader examination of future space programs can be found in the record of hearings held by the House Science and Technology Committee in July 1975 and January 1978 entitled "Future Space Programs" in both cases.

II. Space Stations, Colonies, and Manufacturing Facilities

(BY MARCIA S. SMITH, ANALYST IN AEROSPACE AND ENERGY TECHNOLOGY)

The Skylab program (described in chapter six) marked the beginning of the space station era for the United States. The space shuttle (see chapter seven) carrying a Spacelab module could be considered a relatively small, short duration space station.

There has been considerable discussion about future generation space stations. One suggestion is to link a number of Spacelab modules together to form larger, more permanent space stations, while another is to use the shuttle's large exernal tank as a space station. In the latter concept, the tank would be carried into orbit along with the shuttle orbiter (rather than falling back to earth as now planned), purged of any remaining fuel, and provided with appropriate environmental conditions. Early Skylab designs had considered the possibility of using a spent rocket stage as a space station, so preliminary investigations of such a possibility have already been accomplished.

The varieties of experiments that could be done in one of these space stations would be effectively an extension of what was done on Skylab and what is planned for Spacelab (crystal growth, experiments with vaccines, metallurgy, etc.). The term "space manufacturing facility" has been coined to refer to permanent space stations which would manufacture materials which would primarily be used in space, such as components of other space stations or satellite power stations.

The most expansive of the space station/manufacturing facility concepts is that advocated by Gerard O'Neill of Princeton University, conceived as accommodating 10,000 people and much of Earth's industry. O'Neill has suggested that the bulk of the colony could be constructed from materials mined on the moon and/or asteroids (see section VII), and could be used as a manufacturing facility for satellite power stations (see section III). According to the O'Neill concept, rather than being located in Earth orbit, the facility could be located at one of the Lagrange coordinates [1] located equidistant from the Earth and Moon.

III. Satellite Power Stations

(BY MARCIA S. SMITH, ANALYST IN AEROSPACE AND ENERGY TECHNOLOGY)

In an age of increasing concern about future energy sources, one concept being considered is that of the satellite power station (SPS), which would collect the Sun's energy in space, convert it into electricity, and beam it to Earth in the form of microwaves where it would be reconverted into electricity.

[1] The Lagrange coordinates are moving points in space where the gravitational forces of the Earth and Moon cancel each other out. There are five of these points in the Earth-Moon system, two of which are considered stable enough to support a space colony (each is 240,000 miles or 384,000 kilometers from Earth and Moon).

The Department of Energy (DOE) is the lead agency for the SPS concept, although NASA is responsible for that part of the system dealing with space systems. Several designs have been investigated for SPS's, and NASA and DOE have recently concluded that the design with the greatest technological feasibility at this time is a photovoltaic solar array of silicon solar cells. According to the most recent scenario, a launch vehicle would carry construction materials into geosynchronous orbit [2] where workers would build solar arrays approximately 5 by 10 kilometers. Each SPS would consist of two solar arrays separated by a device for converting the electricity generated by the solar arrays into microwaves. The microwaves would then be transmitted to receiving and rectifying antennas (rectennas) located on the planet's surface where the microwaves would be reconverted into electricity and fed into a utility power grid. The current NASA/DOE plan calls for each SPS to provide 5,000 megawatts of power into the electric utility power grid.

There are many unknowns in the SPS proposal: environmental effects of microwaves both on the ionosphere and on biota near the rectenna; land use for the rectennas may pose a problem, especially if it is concluded that a large exclusion area is required around each rectenna to protect biota from microwave radiation; there may be a problem of radio frequency interference with either space-based or land-based communications systems; and studies need to be made of possible damage to the atmosphere from launch vehicle emissions.

It also has been suggested that SPS's could be constructed from materials mined on the Moon or asteroids, and a provision was included in the FY 79 National Science Foundation Authorization Bill to have the NSF Director determine if his agency should conduct a feasibility study of this proposal, and if he determined that such a study was necessary, that $500,000 be made available from the general NSF funds for it. Dr. O'Neill has also suggested that a space colony at one of the Lagrange coordinates (see previous section) could be used as an SPS manufacturing facility.

IV. Single-Stage-to-Orbit

(BY BARBARA A. LUXENBERG, ANALYST IN AEROSPACE AND ENERGY TECHNOLOGY)

Since the 1960's, industry has been interested in concepts for a fully reusable single-stage-to-orbit (SSTO) space vehicle instead of the partially reusable space shuttle. Different SSTO configurations have been studied over the years which would: (a) utilize novel structural designs to decrease reentry drag; (b) substantially decrease the structural weight while increasing the thrust; or (c) greatly increase vehicle size to increase thrust. Some of the studies suggested development of an SSTO design which would utilize a dual fuel rocket propulsion system in which a relatively high density hydrocarbon fuel would be burned with oxygen at lift-off to some intermediate velocity, at which point there would be a transition to hydrogen fuel.

[2] Geosynchronous orbit is located 35,800 kilometers above the Earth's equator. An object in geosynchronous orbit will remain in a fixed position relative to any point on the Earth.

NASA's Langley Research Center has conducted several studies (both in-house and contracted) to determine feasible designs and technological and propulsion developments necessary for space delivery systems based on the SSTO concept. Martin Marietta Corporation and Boeing Aerospace Company conducted studies on SSTO concepts for Langley. The constraints of their studies were that the vehicle be designed to have a shuttle-type payload capacity (29,250 kilograms to 376 kilometers or 65,000 pounds to 235 miles, at 28 degrees inclination) and use liquid oxygen and liquid hydrogen propellants. Follow-on studies assessed the value of using a liquid hydrogen/hydrocarbon dual fuel system. The concepts studied were a fully-fueled horizontal takeoff assisted by a sled; a partially-fueled horizontal takeoff with in-flight refueling; and a fully-fueled vertical takeoff. All concepts included horizontal landing.

The Boeing SSTO configuration is a 64.8 meter (216 foot) long delta-wing vehicle using titanium and other alloys, and is designed for a sled launch. It would cost an estimated $3 billion to build (1976 dollars) and put payloads in orbit for about $9/kilogram ($20/pound). The estimated cost per flight would be $1.6 million. The Martin Marietta design is for a 61.2 meter (204 foot) vehicle which would be vertically launched and composed of aluminum and composite materials. This design would cost approximately $5.3 billion to build (1976 dollars) and could place payloads in orbit for approximately $12–13/kilogram ($26–29/pound). The estimated cost per flight is $1.2 million.

Langley followed the two industry studies with its own on possible technical advances which would be necessary to have a reusable space transportation system such as an SSTO. The design studied by Langley would be for a vehicle which could approximate airline operations. That is, propellants, rather than ground testing and support, would be the major cost factor. The vehicle would be reusable and more independent than previous space vehicles in that it could check itself out, using computers, on the ground and in orbit.

As NASA has not yet set a target date for a decision on a second generation space transportation system to follow the shuttle in the 1990's, studies on SSTO concepts, as well as other advanced systems, remain preliminary in nature.

V. Multipurpose Space Platforms

(BY LANI H. RALEIGH, ANALYST IN AEROSPACE AND ENERGY TECHNOLOGY)

The increasing popularity of the geosynchronous satellite, particularly for space communications, is accompanied by the threat of overcrowding of the more desirable locations of the geosynchronous arc. In the future, such crowding could lead to harmful mutual radio interference. Although some techniques have been developed to reduce the possibility of mutual interference, many view the only long-term solution to the problem to be geosynchronous space platforms. Utilizing the capabilities of the space shuttle, the multipurpose space platform would be constructed in geosynchronous orbit.

A number of imaginative designs for such multipurpose space platforms have been proposed. Generally, they include a large platform

which will furnish common support systems such as electrical power, structure, thermal control, orientation, stationkeeping, tracking, telemetry, and command. Specialized mission packages would include those for domestic, international, and regional telecommunications; maritime, aeronautical and land mobile services; navigation; and Earth observation. Typically, multipurpose space platform designs include a large number of powerful antennas and a variety of mechanisms for frequency re-use.

According to proponents, there are potentially a great number of benefits for the use of such space platforms. User costs would be greatly reduced through shared facilities and launches. The large platform could house multiple antennas and on-board processors (for routing traffic) which would be too massive for single mission satellites. The higher effective radiated power of the spot beams would enhance the capacity of the mission. With on-board processors, communications packages could process signals rather than just relaying them. Signals could be switched to one or more service (a telephone call could be sent out on the maritime service), or many signals could be combined (multiplexed) to go to the same destination. This increase in the performance of the space segment could reduce overall costs and investment requirements of the Earth station, enabling a larger number of users to participate in space communications services and permitting more specialized use systems for those users who have traditionally been unable to afford dedicated satellite systems. Experimental risks for new ventures could be minimized by sharing expenses. Thus, testing for marketability could become more desirable. A supplier could begin a service on a small scale and add modules if the service proves successful.

VI. Direct Broadcast Satellites

(BY LANI H. RALEIGH, ANALYST IN AEROSPACE AND ENERGY TECHNOLOGY)

The United States has now developed the capability to use satellites for direct television broadcasting into community receivers and may, in the near future, be able to broadcast directly into individual home receivers. This latter technology has many potentially beneficial uses, but it is controversial in that many nations believe they may not have control over the content of what is broadcast into the individual home receivers. For political, cultural, and economic reasons, many nations want to establish a regime of prior consent for direct satellite broadcasts into home receivers. The United States, along with other nations, has adopted a stance against prior consent because of its policy that the flow of data and information should be unimpeded and therefore should be subject to minimal regulation.

VII. Some Longer Term Options

(BY MARCIA S. SMITH, ANALYST IN AEROSPACE AND ENERGY TECHNOLOGY)

In addition to those programs described above, there are several longer-term options which may be considered. One of these has already been mentioned in section II—Gerard O'Neill's space colony. There are other possibilities which may seem more science fiction than fact at this time: colonies on the Moon; the mining of Moon and aster-

oids either for materials to construct space colonies or satellite power stations or to augment Earth's supplies of minerals; and manned exploration of the solar system.

A. LUNAR COLONIES

The Moon has long been viewed not only as a source of information about the origin of the solar system, but as a staging area for space flights. With only one-sixth the gravity of Earth, space ships could be launched more easily and more economically from the Moon, possibly leading to manned exploration of the solar system. The Apollo program, and the presumed Soviet attempt to also reach the Moon, have been predicated not only on the national prestige aspects of flying to the Moon, coupled with scientific investigations, but the possibility of establishing settlements there.

A design for a lunar colony, called Counterpoint, was developed by two architects in 1975 John R. Dossey and Guillermo L. Trotti;[3] a model of this lunar colony is on display at the National Air and Space Museum in Washington, D.C. The colony was designed for 200 people, sited near the Apollo 15 landing site. The design calls for three landing pods for space vehicles, hangar and repair areas, a refinery and casting complex, a power unit, food production and processing areas, a civic center for recreational, dining, religious, and administrative activities, living quarters for the permanent population and visitors, a laboratory research complex, and a 100-inch reflector telescope.

There is, of course, the possibility of using the Moon as a military base as well. Concerns about such a use were part of what propelled the United States into the Moon race when it appeared that the Russians might get to the Moon first. This was well before the 1967 Outer Space Treaty which states that "Outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means" (Article II). This language would preclude building military bases on the Moon, although it might also preclude other establishments as well if built by a single nation. The United Nations is now in the process of formulating a Treaty on the Moon which would resolve such questions raised by the 1967 treaty.

B. MINING OF THE MOON AND ASTEROIDS

As the population of Earth uses up its natural resources, other sources of needed raw materials will have to be found. One place to look is the asteroids, small planetoids which lie between the orbits of Mars and Jupiter. Although the exact nature of the asteroids is not known, it is speculated that they are either the remnants of a planet which was pulled apart by the gravitational forces of Jupiter, or the material from which a planet would have formed were it not for that gravitational force. In either event, they are expected to be composed of many of the same materials as the other terrestrial planets (Mercury, Venus, Earth and Mars). Little is known about the asteroids at the present time, and some scientists have proposed asteroid

[3] John R. Dossey and Guillermo L. Trotti. Counterpoint: A Lunar Colony. Spaceflight, v. 17, July 1975: 259–268.

reconnaissance missions to assay these bodies and, if they do contain deposits of vauable minerals, attempt to bring one back to Earth (or an orbiting space colony) for refining.

The current status of our knowledge about the asteroids and the reasons some scientists want to continue studying them can be found in the proceedings of the January 1978 NASA sponsored workshop at the University of Chicago, entitled "Asteroids: An Exploration Assessment" (NASA Conference Publication 2053). Another NASA conference was held on near-Earth resources, including both the Moon and asteroids. The results of that conference are published as NASA Conference Publication 2031 "Summer Workshop on Near-Earth Resources."

In addition to the asteroids, the Moon may prove to be a source of minerals. Analysis of the Apollo lunar samples has shown that the lunar rocks have comparably higher concentrations of calcium, aluminum and titanium than Earth rocks, while they have comparably lower concentrations of sodium and potassium. The lunar rocks have so far been found to contain 100 different types of minerals (compared to about 2,000 types on the Earth). Analysis of the lunar samples is an ongoing process, although many lunar scientists now believe that it is time for more lunar exploration, specifically a Lunar Polar Orbiter (LPO) which could survey many previously uncharted areas of the Moon, determine the chemical composition of the Moon's surface in those areas. Congress denied funding for the LPO mission in FY77, so NASA did not request funding for the probe in FY78 or FY79, although the House Science and Technology Committee added $7 million for LPO in the FY78 budget (it was subsequently removed from the final bill).

In the FY79 authorization bill for the National Science Foundation, Congress included a provision that the NSF Director determine whether his agency should conduct a feasibility study of constructing solar power stations from material mined on the Moon or asteroids. If the director decides that such a study is necessary, $500,000 is to be made available from the general NSF funds.

C. MANNED EXPLORATION OF THE SOLAR SYSTEM

Since the early days of science fiction, the possibility of manned flight to other planets has been discussed by space enthusiasts. During the early 1960's, manned flights to Mars were contemplated by some space planners for the 1980's. Such flights would be extremely expensive, especially if they were launched from Earth. Present day launch vehicles could not launch the large type of spaceship required for such flights, although conceivably they could be launched in sections and assembled in orbit. Other plans suggest the use of space colonies or lunar bases as launch sites for massive spaceships.

The primary problems to overcome in long distance/long duration space flight include man's physical adaptation to weightlessness (see chapter eight); psychological problems; launch vehicle development; and economic problems. Depending on the capability of the launch vehicle used and the destination, flights beyond the solar system might take so much time that aging of the crew might present a problem, in which case suspended animation or hibernation (if the processes which

induce hibernation in other animals can be undrstood and transferred to humans) might be desirable. If launch vehicles could be developed which would propel the spaceship at speeds close to the speed of light, Einstein's theory of relativity would come into effect, where time on board the spaceship would be different from time on the home planet. For example, while people on the home planet aged 24 years, the spaceship crew would age only 10 years; while 36,000 years would elapse on the home planet, the crew would experience a time of only 40 years.[4]

[4] Sebastian von Hoerner. The General Limits of Space Travel. Science, v. 37, July 16, 1962: 18–23.
For further information on factors involved in manned exploration of the solar system and galaxy, see the committee print "Possibility of Intelligent Life Elsewhere in the Universe" (Revised, October 1977), House Science and Technology Committee, October 1977.

APPENDIX A

(Office of the White House Press Secretary—June 19, 1978)

THE WHITE HOUSE

The President directed under a Presidential Review Memorandum that the NSC Policy Review Committee (PRC) thoroughly review existing policy and formulate overall principles which should guide our space activities. The major concerns that prompted this review arose from growing interaction among our various space activities.

This review examined and the resultant Presidential Directive establishes:

A government policy oversight system to review and revise space policy as needed;

Ground rules for the balance and interaction among our space programs to insure achievement of the interrelated national security, economic, political, and arms limitation goals of the U.S.; and

Modifications to existing policies, the appropriate extent of the overlapping technology, and product dissemination by the sectors.

This Presidential Directive establishes an NSC Policy Review Committee to provide a forum to all Federal agencies for their policy views, to advise on proposed changes to national space policy, to resolve issues referred to the Committee, and to provide for rapid referral of issues to the President for decision as necessary. This Committee will be chaired by the Director of the Office of Science and Technology Policy, Frank Press. Recognizing that the civilan space program is at the threshold of change, the President has asked the PRC to assess the needs and aspirations of the nation's civil space program. The United States has built a broad national base in space and aeronautics. At issue is how best to capitalize on prior investments and set the needed direction and purpose for continued vitality in the future.

Under the Presidential Review Memorandum the emphasis was to resolve potential conflicts among the various space program sectors and to recommend coherent space principles and national space policy. In focusing upon these issues, the Policy Review Committtee concluded that our current direction set forth in the Space Act of 1958 is well founded and that the preponderence of existing problems was related to interactions and resultant stresses among the various space programs. For this reason, the classified portion of the recently signed Presidential Directive concentrates on overlap questions. It does not deal in detail with the long-term objectives of our defense, commercial, and civil programs. Determining our civil space policy, outlined above, will be the next step.

As a result of this in-depth review, the President's Directive establishes national policies to guide the conduct of United States activities in and related to space programs. The objectives are (1) to advance the interests of the United States through the exploration and use of space and (2) to cooperate with other nations in maintaining the freedom of space for all activities which enhance the security and welfare of mankind. The space principles set forth in this Directive are:

The United States will pursue space activities to increase scientific knowledge, develop useful commercial and government applications of space technology, and maintain United States leadership in space technology.

The United States is committed to the exploration and use of outer space by all nations for peaceful purposes and for the benefit of all mankind.

The United States is committed to the exploration and use of outer space in support of its national well-being.

The United States rejects any claims to sovereignty over outer space or over celestial bodies, or any portion thereof, and rejects any limitations on the fundamental right to acquire data from space.

The United States holds that the space systems of any nation are national property and have the right of passage through and operations in space without interference. Purposeful interference with space systems shall be viewed as an infringement upon sovereign rights.

The United States will pursue activities in space in support of its right of self-defense and thereby strengthen national security, the deterrence of attack, and arms control agreements.

The United States will conduct international cooperative space activtities that are beneficial to the United States scientifically, politically, economically, and/or militarily.

The United States will develop and operate on a global basis active and passive remote sensing operations in support of national objectives.

The United States will maintain current responsibility and management relationships among the various space programs, and, as such, close coordination and information exchange will be maintained among the space sectors to avoid unnecessary duplication and to allow maximum cross-utilization of all capabilities.

Our civil space programs will be conducted to increase the body of scientific knowledge about the earth and the universe; to develop and operate civil applications of space technology; to maintain United States leadership in space science, applications, and technology; and to further United States domestic and foreign policy objectives within the following guidelines:

The United States will encourage domestic commercial exploitation of space capabilities and systems for economic benefit and to promote the technological position of the United States; however, all United States earth-oriented remote sensing satellites will require United States government authorization and supervision or regulation.

Advances in earth imaging from space will be permitted under controls and when such needs are justified and assessed in relation

to civil benefits, national security, and foreign policy. Controls, as appropriate, on other forms of remote earth sensing will be established.

Data and results from the civil space programs will be provided the widest practical dissemination to improve the condition of human beings on earth and to provide improved space services for the United States and other nations of the world.

The United States will develop, manage, and operate a fully operational Space Transportation System (STS) through NASA, in cooperation with the Department of Defense. The STS will service all authorized space users—domestic and foreign, commercial and governmental—and will provide launch priority and necessary security to national security missions while recognizing the essentially open character of the civil space program.

Our national security related space programs will conduct those activities in space which are necessary to our support of such functions as command and control, communications, navigation, environmental monitoring, warning and surveillance, and space defense as well as to support the fomulation and execution of national policies; and to support the planning for and conduct of military operations. These programs will be conducted within the following guidelines:

Security, including dissemination of data, shall be conducted in accordance with Executive Orders and applicable directives for protection of national security information. Space-related products and technology shall be afforded lower or no classification where possible to permit wider use of our total national space capability.

The Secretary of Defense will establish a program for identifying and integrating, as appropriate, civil and commercial resources into military operations during national emergencies declared by the President.

Survivability of space systems will be pursued commensurate with the planned need in crisis and war and the availability of other assets to perform the mission. Identified deficiencies will be eliminated and an aggressive, long-term program will be applied to provide more assured survivability through evolutionary changes to space systems.

The United States finds itself under increasing pressure to field an anti-satellite capability of its own in response to Soviet activities in this area. By exercising mutual restraint, the United States and the Soviet Union have an opportunity at this early juncture to stop an unhealthy arms competition in space before the competion develops a momentum of its own. The two countries have commenced bilateral discussions on limiting certain activities directed against space objects, which we anticipate will be consistent with the overall U.S. goal of maintaining any nation's right of passage through and operations in space without interference.

While the United States seeks verifiable, comprehensive limits on anti-satellite capabilities and use, in the absence of such an agreement, the United States will vigorously pursue development of its own capabilities. The U.S. space defense program shall include an integrated attack warning, notification, verification, and contingency reaction capability which can effectively detect and react to threats to U.S. space systems.

APPENDIX B

(Office of the White House Press Secretary—October 11, 1978)

THE WHITE HOUSE

U.S. CIVIL SPACE POLICY

The President announced today a space policy that will set the direction of U.S. efforts in space over the next decade. The policy is the result of a four-month interagency review requested by the President in June 1978. American civil space policy will be centered around three tenets:

First: Our space policy will reflect a balanced strategy of applications, science and technology development containing essential key elements that will:

Emphasize space applications that will bring important benefits to our understanding of earth resources, climate, weather, pollution and agriculture, and provide for the private sector to take an increasing responsibility in remote sensing and other applications.

Emphasize space science and exploration in a manner that retains the challenge and excitement and permits the nation to retain the vitality of its space technology base, yet provides short-term flexibility to impose fiscal constraints when conditions warrant.

Take advantage of the flexibility of the space shuttle to reduce the cost of operating in space over the next two decades to meet national needs.

Increase benefits for resources expended through better integration and technology transfer among the national space programs and through more joint projects when appropriate, thereby increasing the return on the $100 billion investment in space to the benefit of the American people.

Assure American scientific and technological leadership in space for the security and welfare of the nation and continue R&D necessary to provide the basis for later programmatic decisions.

Demonstrate advanced technological capabilities in open and imaginative ways having benefit for developing as well as developed countries.

Foster space cooperation with nations by conducting joint programs.

Confirm our support of the continued development of a legal regime for space that will assure its safe and peaceful use for the benefit of mankind.

Second: More and more, space is becoming a place to work—an extension of our environment. In the future, activities will be pursued in space when it appears that national objectives can most efficiently be met through space activities.

Third: It is neither feasible nor necessary at this time to commit the United States to a high-challenge space engineering initiative comparable to Apollo. As the resources and manpower requirements for shuttle development phase down, we will have the flexibility to give greater attention to new space applications and exploration, continue programs at present levels or contract them. To meet the objectives specified above, an adequate Federal budget commitment will be made.

Space applications

As a part of his overall review and in accordance with his desire to increase emphasis on uses of space for a wide variety of practical and economic benefits the President made the following decisions:

Remote Sensing Systems.—Since 1972 the United States has conducted experimental civil remote sensing through LANDSAT satellites. There are many successful applications and users, including Federal departments, other nations, a number of states, and a growing number of commercial organizations. The United States will continue to provide data from the developmental LANDSAT program for all classes of users. Operational uses of data from the experimental system will continue to be made by public, private, and international users. Specific details and configurations of the LANDSAT system and its management and organizational factors will evolve over the next several years to arrive at the appropriate technology mix, test organizational arrangements, and develop the potential to involve the private sector.

Integrated Remote Sensing System.—A comprehensive plan covering expected technical, programmatic, private sector, and institutional arrangements for remote sensing will be explored. NASA will chair an interagency task force to examine options for integrating current and future systems into an integrated national system. Emphasis will be placed on defining and meeting user requirements. This task force will complete its review prior to the FY 1981 budget cycle.

Weather Satellites.—Separate operational requirements for meteorological data over the past two decades have led to separate Defense and Commerce's National Oceanic and Atmospheric Administration (NOAA) weather satellites. The Defense community, NASA, and NOAA will conduct a review of meteorological satellite programs to determine the degree to which these programs might be consolidated in the 1980s and the extent to which separate programs supporting specialized defense needs should be maintained. The possibility of integrated systems for ocean observations from space will also be examined.

The Private Sector.—Along with other appropriate agencies, NASA and Commerce will prepare a plan of action on how to encourage private investment and direct participation in civil remote sensing systems. NASA and Commerce will be the contacts for the private sector on this matter and will analyze proposals received before submitting to the Policy Review Committee (Space) for consideration and action.

Communications Satellite R&D.—United States leadership in communications satellite systems will be supported by NASA. Selected

technological opportunities to provide better frequency and orbit utilization and other longer-term opportunities will be pursued.

Communications Satellite Services.—Some areas of communications services—such as educational and health services and basic communications services for remote areas—involve low-volume and intermittent use and have evidenced little interest from commercial satellite operators. The Department of Commerce's National Telecommunications and Information Administration (NTIA) will assist in market aggregation, technology transfer, and possible development of domestic and international public satellite services. This direction is intended to stimulate the aggregation of the public service market drawing on the technology that is already in existence. The Agency for International Development and Interior will work with NTIA in translating domestic experience in public service programs into potential programs for lesser-developed countries and the remote territories.

Future Applications and Economic Activity.—It is too early to make a commitment to the development of a satellite solar power station or space manufacturing facility due to the uncertainty of the technology and economic cost-benefits and environmental concerns. There are, however, very useful intermediate steps that will allow the development and testing of key technologies and experience in space industrial operations to be gained. The United States will pursue an evolutionary program that is directed toward assessing new options which will be reviewed periodically by the Policy Review Committee (Space). The evolutionary program will stress science and basic technology—integrated with a complementary ground R&D program—and will continue to evaluate the relative costs and benefits of proposed activities.

Space science and exploration

The President reviewed the space science and planetary exploration program and determined that the United States' priorities at any given time will depend on the promise of the science, the availability of the particular technology, and the budgetary situation. The United States will maintain a position of leadership in space science and planetary exploration and will:

Continue a vigorous program of planetary exploration to understand the origin and evolution of the solar system. The goal in the years ahead is to continue the reconnaissance of the outer planets and to conduct more detailed exploration of Saturn, its moons, and its rings; to continue comparative studies of the neighboring planets, Venus and Mars; and to conduct reconnaissance of comets and asteroids.

Utilize the space telescope and free-flying satellites to usher in a new era of astronomy, as we explore interstellar molecules, quasars, pulsars, and black holes to expand our understanding of the universe.

Develop a better understanding of the sun and its interaction with the terrestrial environment through space systems—such as the Solar Maximum Mission and the Solar Polar Mission—that will journey towards the sun and earth-orbiting satellites that will measure the variation in solar output and determine the resultant response of the earth's atmosphere.

Utilize the space shuttle and spacelab, alone and in cooperation with other nations, to conduct basic research that complements

earth-based life science investigations and human physiology research.

Our policy in international space cooperation will include two basic elements: (1) to pursue the best science available regardless of national origin and expand our international planning and coordinating effort; and (2) to seek cooperative support for experiments-spacecraft which have been chosen on sound scientific criteria.

Increased benefit for resources expended

As a result of the President's review, decisions were made that will increase the benefit to the United States for resources expended.

Strategy to Utilize the Shuttle.—The Administration will make incremental improvements in the shuttle transportation system as they become necessary. Decisions on extending the shuttle's stay time in orbit and future upper stage capabilities (e.g., the reusable space tug and orbital transfer vehicle) will be examined in the context of our emerging space policy goals. An interagency task force will make recommendations on what future capabilities are needed. This task force will submit the findings to the Policy Review Committee (Space) prior to FY 1981 budget cycle.

Technology Sharing.—The Policy Review Committee (Space) will take steps to enhance technology transfer between the space sectors. The objective will be to maximize efficient utilization of the sectors while maintaining necessary security and current management relationships.

Background

Early in his Administration, the President directed a National Security Council review of space policy. The emphasis was on coherent space principles and national space policy and did not deal in detail with the long-term objectives of our defense, commerical, and civil programs. The review, completed in May 1978, resulted in a Presidential Directive that set the basic framework for our civil space policy completed last week. The President's May 1978 directive established a Policy Review Committee (Space) to provide a forum for all Federal agencies in which to advise on proposed changes to national space policy and to provide for rapid referral of issues to the President for decision. This Committee is chaired by the Director of the Office of Science and Technology Policy, Frank Press. In June 1978 the President directed the Policy Review Committee (Space) to assess the future needs of the nation's civil space program, and their report formed the basis for the policy decisions outlined here. The following agencies and departments participated: The National Aeronautics and Space Administration, Commerce, Interior, Agriculture, Energy, State, National Science Foundation, Agency for International Development, Defense, Director of Central Intelligence, Joint Chiefs of Staff, and Arms Control and Disarmament Agency, as well as the Domestic Policy Staff, the National Security Council Staff, and the Office of Management and Budget.

For further information on the above, contact the Office of Science and Technology Policy (Art Morrissey/395–5736) or the National Aeronautics and Space Administration's Director of Public Affairs (Bob Newman/755–3828).

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